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SYNCHRONOUS-MULTIPLEX TELEGRAPHY IN ACTUAL PRACTICE.

By PROF. EDWIN J. HOUSTON.

It will interest the public generally to learn that Mr. Patrick B. Delany has successfully put into active operation his synchronous-multiplex system of telegraphy between the cities of Boston and Providence, R. I., a distance of about fifty miles.

The line is constructed of number six galvanized iron wire. For the purpose of securing one wire for operation in case of the accidental interruption of the other, and with a view to extension of the system, two wires have been strung. It will of course be understood that each of these wires is intended for separate use under any of the divisions of which the synchronous-multiplex system is capable; viz., any number from a single circuit up to seventy-two separate and distinct circuits over one and the same wire; or, as these are generally used in actual practice, into six fast, or twelve slower Morse circuits; or into thirty-six, or seventy-two printing circuits.

When the possibilities of the Delany synchronous-multiplex system were first brought before the public, grave doubts were expressed by some, if not by a majority of the leading electricians of the country, as to the possibilities of its actual operation under the conditions of commercial practice. Many believed that although it might be operative under the conditions of an artificial line, established in the laboratory

by means of resistance coils and condensers, that when put into actual operation the conditions necessary for continuous working could not be maintained.

It may be interesting, briefly to review some of the many objections that at the outset were urged against the practical workings of the system. As is, of course, understood, the possibility of the successful operation of the synchronous-multiplex system is dependent on the continuance of the synchronous rotation of the distributing wheel at the transmitting and receiving ends of the line. In Mr. Delany's system, as the reader will probably recall, the synchronous rotation of the discs at each end of the line is maintained by timed, electrical impulses, thrown into electro-magnetic motor devices, by the vibration of similar tuning forks placed one at each end of the line. Now it was urged, and perhaps with some show of reason, that although it might be possible to maintain the synchronous vibration of these forks in a room, where any necessary adjustment of their rate of vibration could be made by an attendant, yet it would clearly be impossible to maintain such synchronous vibration at stations widely separated from each other, since the mere difference of temperature at the two stations would, unless automatically compensated for, be sufficient to throw the two forks out of synchronism.

Another difficulty that in the opinion of many presented an insuperable obstacle to the practical application of the system was the static charge of the line. It was thought that the line could not in practice be discharged with sufficient rapidity to permit the transference thereon of the numerous separate and distinct electrical impulses necessary in this system. It was feared that before the line could be freed from the charge given it by one impulse, another would be sent over it by the distributor, and that these two would necessarily interfere with each other.

These, and many other difficulties, were urged as necessarily fatal to the success of the system. It is to the credit of Mr. Delany that he has so ingeniously met and overcome all these difficulties, and has established his invention on a commercial basis. But let the actual facts of the case speak for themselves.

Dividing one of the wires between Boston and Providence into six separate circuits, it was worked for long periods at the rate of forty words per minute on each of the circuits so established. Dividing the

line into twelve Morse circuits, it was similarly worked at the rate of twenty words per minute on each line.

Thirty-six printing circuits have been worked between the two cities at the rate of from four to five words per minute; while seventy-two printing circuits were similarly worked at the rate of from two to three words per minute.

The circuits above referred to have all been operated in one and the same direction at the same time, or have been operated one-half in one direction and the remaining half in the opposite direction, or other combinations of the same number of separate and distinct circuits have been employed.

In order to practically note the effect produced by increasing the length of the line, the two wires were joined together at Providence, thus providing one continuous circuit from Boston to Providence and back again to Boston, with separate grounds at each end in Boston. Over this double distance of about one hundred miles, the circuits were operated, as above mentioned, without any diminution of speed.

Further experiments introducing artificial resistances of 3,000 ohms, or an equivalent of about 300 miles of line, and of 2½ microfarads of static charge, demonstrated the entire success of the system, under these conditions, with only a slightly diminished speed.

Employing the line as a sextuplex, on Saturday, July 12, 1884, 1,000 words were transmitted over one of the sextuplex circuits Boston via Providence to Boston, and received, at the rate of thirty-five words per minute, by sound, by Morse operators, who had never seen the system before that week.

Employing the line as a duodeciplex, 1,100 words were transmitted over one of the twelve lines so provided, at the rate of twenty words per minute and perfectly received by sound. An increase in the resistance of the line of 9,000 ohms, in addition to the normal resistance of the 100 miles of wire, in the two wires joined as one, did not affect the synchronism, or prevent the perfect transmission of the messages.

The synchronous-multiplex system of telegraphy has now been in actual operation between Boston and Providence, under the various conditions above mentioned, during the last thirty days. During that entire time, the synchronism has been maintained between the Boston and the Providence instruments without ten minutes interruption, excepting, of course, when the instruments were purposely stopped, or were

interrupted for the purposes of experiment, or were disturbed by crosses or breaks in the wires of the main line. When thrown out of synchronism by any of these causes, the instruments at the ends of the line, in all cases, came automatically into synchronism within one and a half minutes, without the intervention of the operator at either the Boston or the Providence end of the line.

Mr. Delany has availed himself of the opportunity which the additional line afforded him of trying practically things for which he believed his system adapted, and for which he originally intended it. One of the many purposes to which he showed the applicability of the synchronous-multiplex system would seem to add so greatly to its commercial value when in actual operation, that it may be well to explain it at length.

Connecting at Providence one of the sextuplex circuits established in one of the wires, to the end of the second wire at Providence, a message transmitted from Boston, over the sextuplex circuit so connected, was received in Boston on the second wire clearly and perfectly transmitted.

This experiment would seem to show that the synchronous-multiplex system is applicable not only to the connection of terminal stations, whereby the wire may be divided into the numerous circuits claimed for it, but that the six circuits, for example, obtained from a single wire, may be connected at the terminal stations at the two ends of the main line where a distributing instrument is situated, by independent wires run so as to reach the outlying cities beyond. In this manner each of these cities will be furnished with an exclusive circuit through the divided wire.

With, for example, a distributor in New York, connected by a single wire with one in Boston, and divided into say six Morse circuits, a single wire, extending to Providence, could be connected at Boston to the No. 1, of the six multiplex circuits, while Lowell, could be connected to the No. 2, of the multiplex circuits; Portsmouth to the No. 3, of the multiplex circuits; Worcester to the No. 4, of the multiplex circuits; Lawrence to the No. 5, of the multiplex circuits; and finally Lynn to the No. 6, of the multiplex circuits, thus affording each of these six cities direct circuits over one and the same wire to New York, through the medium of the distributor at Boston, without any repetition of the dispatches.

In like manner, if so desired, six cities adjacent to New York,

within distances, of say from 75 to 100 miles from New York, might be connected with Boston, through the medium of the New York distributor, or the outlying cities themselves might be put into communication with each other.

Under the present system of telegraphic communication, nearly all these outlying cities are compelled to send their messages on to Boston or New York, from which places they are repeated to their destination.

The connection above referred to may be better understood by reference to the figure. *A* and *B* represent the synchronized distributors situated at Boston and Providence respectively and connected with the main line wire *Q Q*. The second wire Q^1 Q^1, which ordinarily has no connection with the distributors *A* and *B*, is for the purposes of this experiment connected in the manner shown. In the figure the contacts are connected in groups of six, or in other words the main line *Q Q*, is divided into a sextuplex. The trailing arms at *A* and *B*, are shown in contact with one of the No. 6, contacts at *d* and *h*, respectively. Polarized relays *R*, R^1, R^2, R^3, and R^4, are connected respectively to five of the six circuits so provided. The sixth circuit in this case, it will be observed, is left unconnected to the polarized relay R^5. The relays are connected by means of switches *S*, S^1, S^2, S^3, S^4 and S^5, with the keys *K*, K^1, K^2, K^3, K^4 and K^5, whose front and back stops are connected with the split battery *M B*, grounded at *Y*. It will also be observed that the polarized relays *R*, etc., can be connected with the keys, or with the ground at *X*, and can therefore be used either for transmitting or receiving.

The station at Providence is similarly provided with the polarized relays R^o, R^i, R^{ii}, R^{iii} and R^{iv}, switches S^o, S^i, S^{ii}, S^{iii} and S^{iv}, keys K^o, K^i, K^{ii} K^{iii} and K^{iv} and main battery M^1 B^1, split and grounded at *Z*, and all connected as shown.

If now, the circuits being as described, the switch *S*, at Boston, be placed so as to connect the relay *R*, with the key *K*, a message may be sent over the main line *Q*, *Q*, to the Providence end, where it may be connected with a receiving relay and received. Instead of this, however, this circuit is in this case connected by means of the wire *m*, with the Providence end of the second wire Q^1, Q^1. The Boston end of Q^1, Q^1, is connected by the wire *n*, with the relay R^5, which we have referred to as not being connected with the remaining circuit of the sextuplex circuits. Under these circumstances the message sent from Boston to

Providence by the key *K*, through the relay *R*, is received at Boston by the receiving relay R^5, the latter relay being connected as shown by the switch S^5, to the ground at *X*.

When the key *K*, at Boston, is connected to its front stop as shown, an impulse goes out from the main battery *M B*, and traverses the following circuit, viz., through the conducting wire *a*, *a*, to key *K*, switch *S* relay *R*, conducting wire *b*, *b*, *c*, contact *d*, trailing arm *f*, conducting wire *e*, *e*, main line *Q*, *Q*, conducting wire *g*, trailing arm f^1 contact *h*, conducting wire *i*, *j*, *k*, *l*, and the remaining seven contacts to *m*, second main line wire Q^1, Q^1 and conductor *n*, from which it passes through the receiving relay R^5, where it is received, and finally to the ground at *X*, through *o*, S^5, *p*, *q*, *r* and *s*.

Now the practical value of this experiment, as has already been pointed out, consists in the very evident fact that if the message can be sent from Boston to Providence over the sextuplex circuit and received back clearly and distinctly in Boston over an independent wire, then, since it makes no difference in what direction this independent wire may extend, no matter how far its distant end may be from the synchronized distributor, within say the limit of 75 or 100 miles, important cities, lying within that distance of New York, can be readily placed in independent connection with Boston, and the outlying cities of Boston can be placed in independent connection with New York, by the operation of the two synchronized distributors *A* and *B*.

Though the leg Q^1, Q^1 in this case was but 50 miles in length, yet, from what we have already said, it is evident that much greater distances could be successfully operated in this manner. With printing instruments, since seventy-two separate circuits can be maintained, the number of cities that can be connected with one another, by means of but two synchronized distributors is clearly very great.

CENTRAL HIGH SCHOOL,
Philadelphia, July 17, 1884.

ELECTRIC JEWELS.—In the ballet of the Empire theatre, at London, forty dancers have bucklers and helmets provided with incandescent electric lights covered with colored glass, so as to present the appearance of sparkling jewels. There is also a light at the point of each of the lances. The battery which furnishes the current is placed behind the shields and can work for about an hour.—*Lumière Electrique*, May 3, 1884.

AN EXTRAORDINARY EXPERIMENT IN SYNCHRONOUS-MULTIPLEX TELEGRAPHY.

By Prof. Edwin J. Houston.

A most extraordinary experiment, which is not devoid of practical bearings, has quite recently been made by Mr. Patrick B. Delany with his synchronous-multiplex telegraphic system, which is now in operation between Boston and Providence, a distance of about fifty miles.

As the experiment about to be described almost challenges belief in its possibility, I desire to state, that I have seen it myself and can vouch for the accuracy of the facts herein stated.

Wishing to try the adaptability to the synchronous system, of the automatic repeaters employed by other telegraphic systems, whereby great distances are overcome, Mr. Delany, on three different occasions during the past two weeks successfully employed such repeaters with his system, the last trial, viz., that on Monday the 14th of July, being witnessed by myself.

One of the two wires erected by the Multiplex Company between Boston and Providence, was divided into six separate and distinct Morse circuits. The first of these circuits, which we will call No. 1, was operated to Providence, at which place the receiving relay, on that circuit, was connected to the transmitting instrument on No. 2 circuit. In Boston the receiving relay, of No. 2 circuit, was connected to the transmitting instrument of No. 3 circuit. In Providence the receiving relay, of No. 3, circuit was connected to the transmitting instrument of No. 4 circuit. In Boston, the receiving instrument, of No. 4 circuit, was connected to the transmitting instrument of No. 5 circuit. Finally, in Providence the receiving relay or instrument, of No. 5 circuit, was connected to the transmitting instrument of No. 6 circuit. Under these arrangements, the transmitting instruments at both stations were operated by the receiving relays on the other circuit the same as if worked or operated by an operator; in other words the six separate and distinct circuits, established by the synchronizing apparatus between Boston and Providence, were arranged so as to form in reality a continuous wire stretched six times between Boston and Providence, with both of its free ends in Boston.

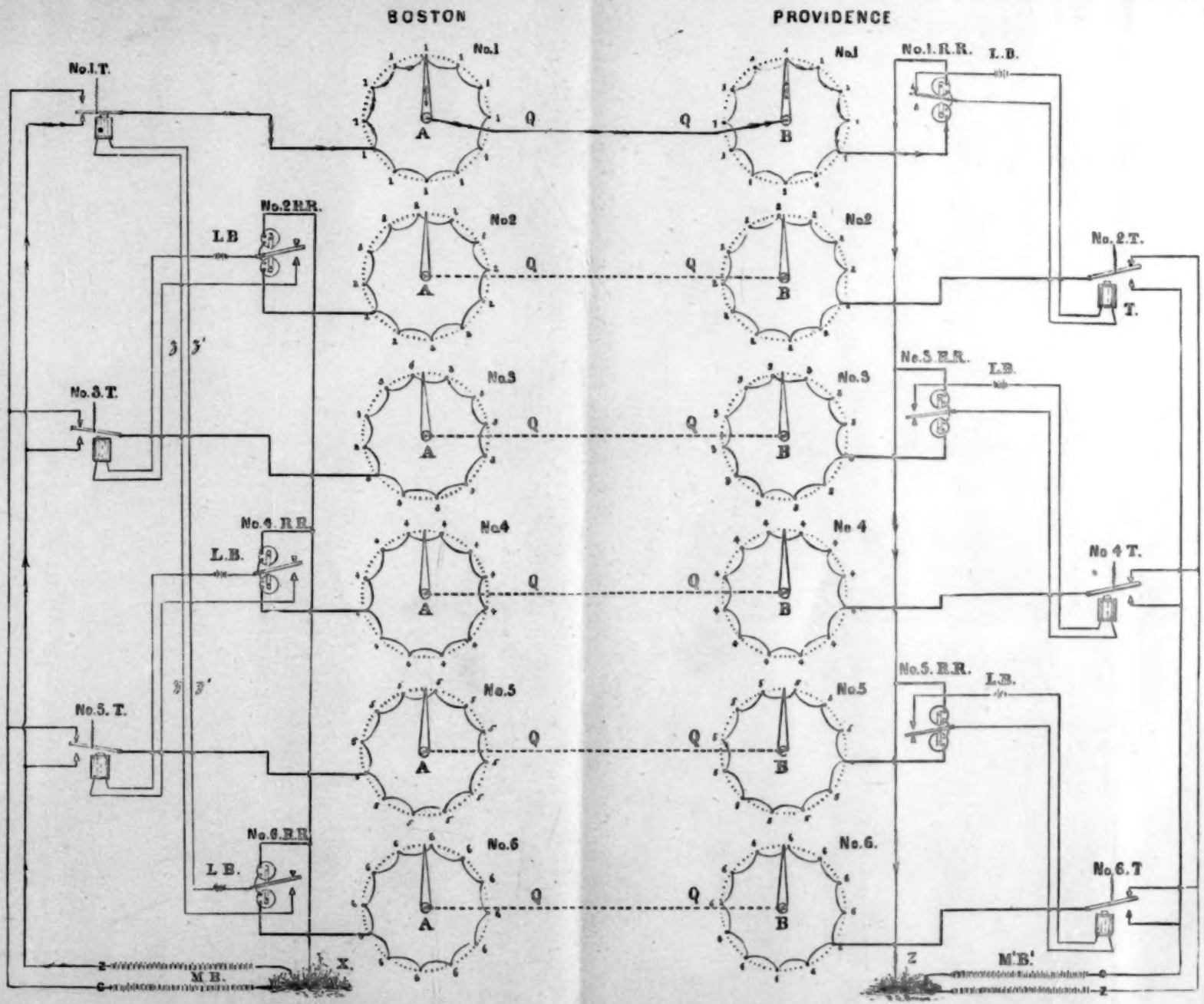
Mr. Delany then transmitted a message on the No. 1 circuit, from Boston to Providence, which was automatically retransmitted from

Providence to Boston on No. 2 circuit; again automatically retransmitted from Boston to Providence on No. 3 circuit; again automatically retransmitted from Providence to Boston on No. 4 circuit; again automatically retransmitted from Boston to Providence on No. 5 circuit, and finally automatically retransmitted from Providence to Boston on No. 6 circuit. Or, in other words, the message sent from Boston on the first circuit, went to Providence, came back to Boston, again went to Providence and came back to Boston, when it again went to Providence and came back to Boston, at which final station it was clearly read by an operator without the loss of a single character, or the slightest impairing of its original clearness, and without the aid of any person except the transmitting operator on the No. 1 circuit in Boston, and the receiving operator on the No. 6 circuit in Boston. All this was done over one and the same wire, so that the message traveled in its back and forth journeys between the two cities, about three hundred miles, or six times the distance between the two cities.

A reference to the drawing will render the preceding explanation clearer. The synchronized distributing instruments, *A* and *B*, situated at Boston and Providence, respectively, are connected by the single main line *Q Q*. The line is divided into six circuits, which we will call respectively No. 1, 2, 3, 4, 5 and 6. For the purpose of rendering the connections clearer, these six circuits have been separately represented with the sychronized distributing instruments connected therewith. It will of course be understood that but a single main line *Q Q*, furnished with but two distributing instruments, viz., one, *A*, at Boston, and the other *B*, at Providence, exists between the two cities.

This being premised, an inspection of the drawing will show that the main battery *M B*, at Boston, split and grounded at *X*, is connected with the No. 1, No. 3 and No. 5 transmitters, which are respectively connected with the No. 1, No. 3 and No. 5 sextuplex circuits of the single main line *Q Q*. At Providence the main battery, M^1 B^1, split and grounded at *Z*, is connected with the No. 2, No. 4 and No. 6 transmitters, which are respectively connected with the No. 2, No. 4 and No. 6 sextuplex circuits of the single main line *Q Q*.

At Providence, the No. 1 receiver is connected with the transmitter of No. 2 circuit, so that a message sent from Boston by No. 1 transmitter, would be received by the No. 1 receiving relay in Providence, when, by means of the local battery *L B*, would have its message



AN EXTRAORDINARY EXPERIMENT IN SYNCHRONOUS-MULTIPLEX TELEGRAPHY.

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repeated by No. 2 transmitter, and sent to Boston over the No. 2 sextuplex circuit of the main line *Q Q*. This message would be received in Boston by the No. 2 receiving relay, when by means of the local battery *L B*, connected with No. 2 receiving relay, would have its message automatically repeated by the No. 3 transmitting instrument at Boston, over the No. 3 sextuplex circuit of the main-line circuit *Q Q*, to Providence, at which place it would be received by the No. 3 receiving relay. This relay, in its turn, through the aid of the local battery connected with it, automatically transmits the message through the No. 4 transmitter, over the No. 4 sextuplex circuit of the main line *Q Q*, to Boston, at which place it is received by the No. 4 receiving relay. This relay, in its turn, through the local battery *L B*, connected therewith, automatically repeats the message to the No. 5 transmitting instrument, over the No. 5 sextuplex circuit of the main line *Q Q*, to Providence, where it is received by the No. 5 receiving relay. Finally this relay, in its turn, through the intervention of the local battery *L B*, connected therewith, automatically repeats the message to No. 6 transmitter, over the No. 6 circuit to Boston, at which place it is received by the No. 6 receiving relay, by the operator stationed at the Morse instrument connected with that relay. This receiving relay is, in reality, shown in the drawing as connected with No. 1 transmitting instrument at Boston. The purposes secured by means of this connection will be hereafter explained.

Briefly, the course taken by the message in its journeys to and from the two cities, is as follows, viz.:

From Boston, by No. 1 transmitter over main line to No. 1 receiving relay at Providence.

From Providence, automatically repeated to No. 2 transmitter, and sent over main line through No. 2, sextuplex circuit to No. 2 receiving relay at Boston.

From Boston, automatically repeated to No. 3 transmitter, and sent over main line through No. 3, sextuplex circuit to No. 3 receiving relay at Providence.

From Providence, automatically repeated to No. 4 transmitter, and sent over main line through No. 4, sextuplex circuit to No. 4 receiving relay at Boston.

From Boston, automatically repeated to No. 5 transmitter, and sent over main line through No. 5, sextuplex circuit to No. 5 receiving relay at Providence.

Finally, from Providence, automatically repeated to No. 6 transmitter over the main line through No. 6, sextuplex circuit, to the No. 6 receiving instrument at Boston, where it is received by the operator.

It is not necessary, as might be supposed from the drawing, that the characters received on the group of segments comprising No. 1 circuit must, necessarily begin to return on the next adjoining segment of No. 2 circuit. Suppose, for example, that a character concluded on the segments of No. 1 circuit, where the trailing contact indicates on the drawing. By the time the armature of the relay has moved in response to this character, and has placed No. 2 circuit in connection with the battery for return transmission, the trailing contact may be on the second or third contact of the No. 2 circuit. This, however, will make no difference, since both the distributing arms are synchronous, so long as the rotating arms pass over two or three of the No. 2 segments, while the armature of the transmitting magnet is in contact with either of the poles of the battery.

When we consider that a message made up of many words, each word containing numerous letters, each letter consisting of numerous separate and distinct characters, and each character, under the synchronous multiplex system, consisting of numerous impulses, was transmitted with certainty over a single wire, back and forth, this number of times, without the slightest interruption the one with the other, the fact almost challenges belief.

While these results may appear almost incredible, what I am about to describe may at first thought seem impossible. I will endeavor, however, to give such a description of this experiment as I saw it actually made, as will persuade the reader, that so far from being impossible, its possibility must necessarily follow as a natural result of the exquisitely maintained synchronism secured by Mr. Delany's ingenious inventions.

After having successfully established by actual trial, the possibility of the use of repeaters in his synchronous system, Mr. Delany connected the relay of the sixth circuit in Boston, where the message was received, with the transmitting instrument on No. 1 circuit. Now under these conditions, on making one dot on No. 1 instrument, this dot started on its zigzag way, to and from Providence, in the manner already described, only, instead of terminating on the sixth circuit in Boston, as in the previous experiment, the same dot was automatically retransmitted into the first circuit, and again sent on

its journeying between the two cities, only on its arrival at the sixth circuit, in Boston to be again automatically retransmitted over this same winding route.

An inspection of the drawing will render this connection clearer. Instead of the message being received by an operator stationed at the No. 6, receiving relay at Boston, this instrument is furnished with a local battery, *L B*, and connected by means of the conducting wire *z z*, and $z^1 z^1$, with the No. 1 transmitting instrument at Boston. By this means, therefore, the operator at the No. 6 receiving relay, is dispensed with, since this receiving relay again automatically sends the signal by means of the No. 1, transmitting instrument, on its ziz-zag way between the two cities, until the No. 6, transmitter at Providence, again sends it to the No. 6, receiving relay at Boston, which again automatically repeats it by the No. 1, transmitter, over the six circuits between the two cities, and so on indefinitely.

In this manner, then, the original signal kept passing from city to city, over the different circuits, in perfect rotation, without the intervention of any operator, save the one who first started the signal on its ceaseless journeyings.

Timing the intervals of the returns of the original signal between the two cities over the sextuplex circuits, it was observed that it traveled between Boston and Providence over these six circuits 300 times; or covered the distance between Boston and Providence, 1,800 times in each minute, thus making an entire distance of 1,500 miles a second, or 90,000 miles a minute; or for five minutes that a dot was kept going, the original signal, in that short time traveled no less than 450,000 miles, or eighteen times as far as the entire distance around the world at the equator.

Of course it will be understood that most of this time was taken up by the automatic movements of the armatures of the receiving relays, and the levers of the transmitting instruments. The experimental figures so obtained, however, furnish interesting data as to the rapidity, precision and certainty with which these masses of matter may be influenced by the electric current.

An observer, noticing the progress of this experiment, and reflecting on the numerous complex conditions requisite for its successful accomplishment, cannot but be singularly impressed by its extreme wierdness. Bearing in mind the exceeding complexity of structure of the synchronous-multiplex message, and the necessity for maintaining practically absolute

synchronism between the distributing and receiving instruments at each end of the main line, a feeling of incredulity almost unconsciously arises in the listener's mind. Surely this wierd traveler must miss some of his numerous connections, and once missed, his journeys are at an end forever. But when the signals are heard recurring with their automatic regularity, as though tossed to and fro between the cities by a mighty juggler; when they are heard as mysterious whisperings in the air, that follow too rapidly on one another to permit more than a part to be intelligently received, we almost lose sight of the actual conditions of the experiment, and begin to vaguely doubt whether Mr. Delany has not received a visit from Puck, who is bewildered by the rapidity with which he is forced to travel; and when the strange repetitions of the original signal follow one another with such rapidity and regularity as to produce a kind of a prolonged, but mysterious murmur we are almost disposed to believe that these sounds are the plaints of the Wandering Jew, as he ceaselessly speeds on his never-ending journey.

CENTRAL HIGH SCHOOL,
Philadelphia, August, 1884.

ON THE APPLICATION OF ELECTRICITY AS AN ILLUMINATING AGENT IN ASTRONOMICAL OBSERVATORIES.

By W. S. FRANKS.

The following notes, partly rewritten from a letter in the *English Mechanic* of April 11, 1884, and supplemented by a more detailed description of the apparatus employed, may possibly have some interest for those engaged in electrical work.

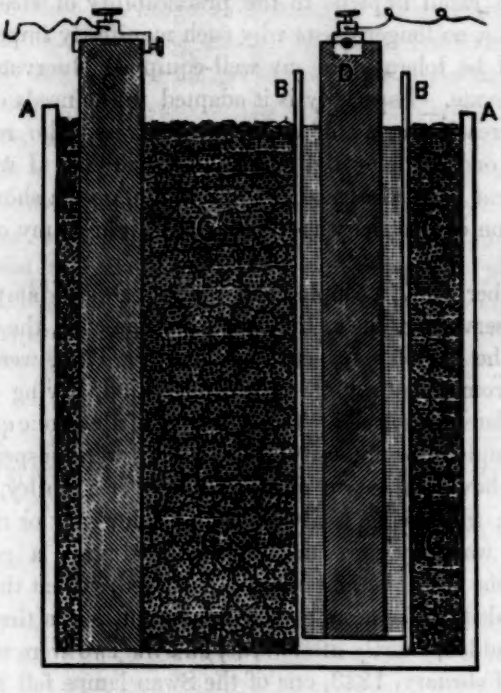
In the first place it may be premised that the efficient lighting of an observatory, including the illumination of the various instruments there used, is a matter that demands some little thought and consideration. Where a gas supply is obtainable it is a comparatively easy matter to carry pipes to the required points; but, even then, gas has many drawbacks, as well as advantages. A gas jet gives off considerable heat, is easily blown out by the wind when the observatory shutters are open, and deposits soot upon any piece of apparatus within which it may be enclosed; added to which is the difficulty of turning down the jets simultaneously, when it is necessary to use the telescopes. If gas is not procurable, and, from the circumstance that the best situation for

an observatory is in the open country, this must often be the case, resort is generally had to oils. These are still worse than gas, for the lamps become black and greasy with constant use, and are a nuisance to keep trimmed. They do, however, possess one advantage over gas, that of being readily carried about to various points. The development of the incandescent systems of Edison, Swan, and others, has given such a rapid impetus to the practicability of electric lighting, that the reason no longer exists why such manifestly imperfect illuminants should be tolerated in any well-equipped observatory, whether public or private. Especially is it adapted to the needs of that large and ever-increasing army of amateur observers, who rejoice in the possession of one of these "lighthouses of the skies." I will, as briefly as is consistent with clearness of description, give a short account of the installation of electricity as the source of light in my own observatory.

In November, 1882, a couple of 2½-candle "Swan" lamps were fitted up in the observatory, one at the equatorial telescope, the other over a desk where the books, maps, etc., are placed. These were worked by a 4-cell bichromate battery of the ordinary kind, having one zinc and two carbon plates to each cell. The cells were of about one quart capacity each, and coupled for intensity. The plates were suspended from a wood frame, having a catgut line, working over a pulley, with a lead counterpoise; thus being easily and quickly lowered or raised. This arrangement was very convenient in use, and gave a good light at starting, but the plates became rapidly polarized, so that the light could not be depended on for more than a few minutes at a time. Another battery was added, shortly afterwards, and the two were worked alternately. In February, 1883, one of the Swan lamps fell from its support, through the spiral spring giving way, and was broken. It was replaced by another, of lower resistance, which was such an obvious improvement in light that I changed the other lamp also. Since that date, then, the same two lamps have been in use until the present time (May, 1884). The two bichromate batteries were dismounted in November, 1883, after a year's work, having, of course, been many times recharged during that interval. I then adopted a new battery, of 3 cells, on the "granule carbon" principle. The performance of this battery is so entirely satisfactory that I may be pardoned for giving a detailed description of it. Fig. 1 shows a cell in section. The outer vessel, *A*, is of salt-glazed earthenware, with a capacity of about two

gallons. *C* is the carbon plate, which is cut out of the crude material from the gas-works, merely having its edges trued with a saw. *B* is the porous cell, containing a zinc plate, *D*. The space *C'* in the outer cell is entirely filled up with pieces of broken carbon, about the size of a small nut. The charge for outer cell is one pound of bichromate of

FIG 1.

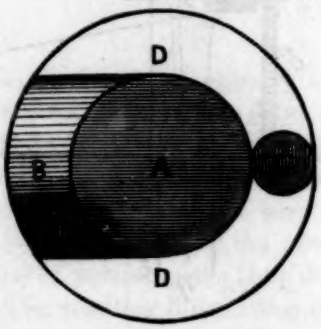


potash, dissolved in one gallon of hot water, to which is afterwards added one pound of sulphuric acid. The inner cell is charged with dilute sulphuric acid, in the proportion of 1 to 10. The three cells are coupled for intensity. When not in use, the zincs are raised out of the liquid, and suspended by loops in the insulated wire (close to binding screw) on small nails. The carbon plate was well paraffined at the exposed end, and a slip of platinum foil placed upon it, under the brass clamp; this effectually prevents oxidation of the latter by the acid creeping up the pores of the carbon. The cells will easily run for three months without recharging, their duty in observatory work being intermittent, not continuous; though, when required, the lamps can be

kept up to full incandescence for hours together. The cost of working has been, thus far, about 3*d.* per week, on the average. The light has been used, ever since its first installation (to the exclusion of any other illuminant), for reading the circles of equatorial telescope, taking time, and recording observations, as well as sketching at the telescope; all of which purposes it answers admirably. Last December (1883), I made a further adaptation of it, which is here described. In using a micrometer, transit, or any other eye-piece having wires, webs, etc., for purposes of measurement, it is necessary to slightly illuminate the field of view in order that they shall be distinctly visible on a dark sky. Under the usual conditions, this requires a somewhat complicated arrangement of lamp, prisms, counterpoise, and so forth. The particular method by which the electric light has been utilized in my own case, is, to the best of my knowledge, novel. I described it in the *English Mechanic* of April 11, 1884 (page 124), and quote therefrom, with but verbal alterations. [It is especially intended for the Newtonian reflector, which is, by far, the best known and most used construction of that class of instruments.]

"When the glasses are removed from the eye-piece, and the eye

FIG. 2.

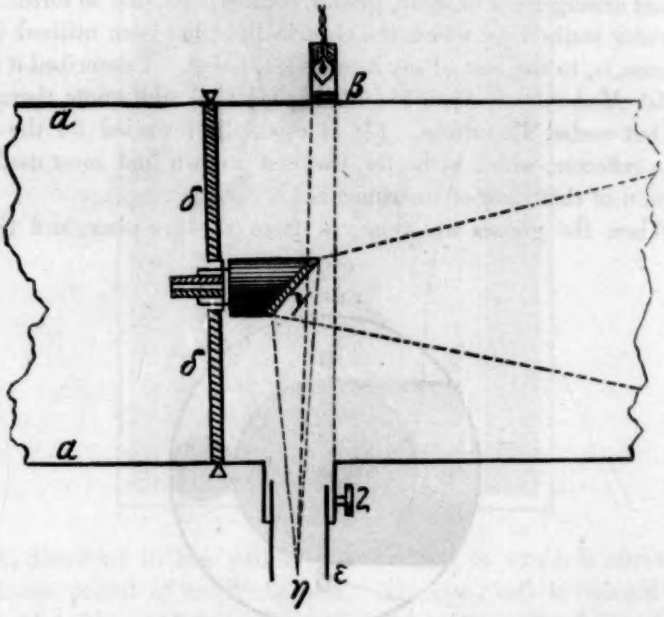


applied thereto, we see an appearance like that represented in Fig. 2, where *A* is the plane mirror, *B* part of its support, and *D* an annular space surrounding plane (in reality the opposite interior of main tube). On the far side of main tube a hole is pierced, so that its circular outline shall be just comprised between the outer ring bounding *D* and the plane *A*; this appears at *C*.

[Reference to Fig. 3 will best elucidate the general arrangement.

α is a part of the main tube, open at one end, closed by the speculum at the other; β the illuminating apparatus, placed over the hole C (in Fig. 2); γ the plane mirror, fixed at an angle of 45°; δ δ, two of the three springs carrying the plane mirror; these are seen *edgewise* from either end of the main tube; ε the draw-tube, to which the various eye-pieces are fitted; ζ the focussing screw; and η the focal point of the converging cone of rays from speculum, which impinge on the plane mirror, and thence are reflected at right angles. The direct rays from β will thus enter the eye-piece along with the reflected cone of rays from γ, as they just miss the plane mirror.]

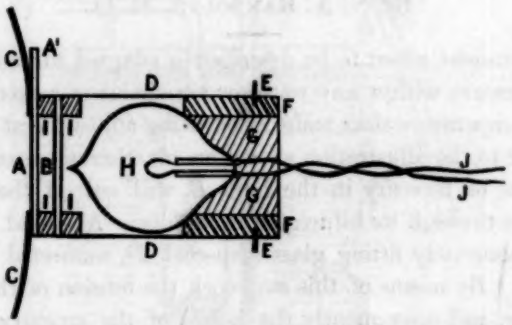
FIG. 3.



In Fig. 4 the illuminating apparatus is shown separately. A is a slip of red glass (other colors can be used at pleasure), which can readily be withdrawn or inserted by the fingers at A^1; B, a circle of opal glass, held by thick india-rubber washers I, I, on each side; this is to mitigate the light, which would otherwise be too strong; C, the base plate, of stout sheet brass, attached to main tube by four screws; D, a short piece of mandrel-drawn tubing, in which the lamp slides; E, E, pins in lamp holder, working in bayonet slots; F, a boxwood ring, accu-

rately fitting inside *D*; *G*, a cork socket for lamp; *H*, the "Swan" lamp (2½-candle); *J*, *J*, insulated wires from lamp. The tube *D* is soldered to base plate *C*, a slot being left on its upper side to receive the slip *A*. The boxwood ring was baked in an oven and soaked in melted solid paraffin. A good paraffined cork was tightly fitted within the boxwood ring, and hollowed at one end to receive the Swan lamp. The insulated wires were scraped, and passed through the cork, the ends being left projecting a few inches whilst being soldered to the platinum loops; on drawing back the wires the lamp was firmly pressed into its socket, and the wires twisted together nearly up to their junction with binding screws on stand of telescoe; this made a good, sou nd

FIG. 4.



connection. [The weak point of the ordinary Swan lamp holder is the *brass* spiral spring; this will *not* stand the damp of the observatory, as I have noticed the brass become so excessively brittle that it falls to pieces on being touched. The last time this occurred I substituted a spring of *copper* wire (this was on the desk lamp), which has shown no such tendency, and is perfectly good at the present time. However, I consider the method of mounting the lamp described above as infinitely preferable.] The resulting illumination of the field for micrometer work is, in every way, satisfactory; the lamp is instantly slid in or out of its brass socket tube, and used for reading the circles, or sketching; indeed, for the last-named purpose it is simply invaluable, the lamp being hung over the eye-piece, and a switch, within arm's length, enables the light to be instantly put on or shut off."

The electric incandescent lamp *must* be the light of the future for the observatory; it is free from the objections to gas and oils and is immensely superior to them in point of convenience.

The only observatories, that I know of, in which the incandescent lamp is used for micrometer work (the details of the way in which it is applied, seem to be different in every one), are the following:

Melbourne, Australia, R. L. J. Ellery, F.R.S.

O'Syalla, Hungary, Dr. N. de Konkoly.

Herény, Hungary, M. E. de Gothard.

Hilgay, Norfolk, England, Canon St. V. Beechey.

Observatory, 1 *High street, Leicester, England*, May, 26, 1884.

A METASTATIC HEAT REGULATOR.

By N. A. Randolph, M. D.

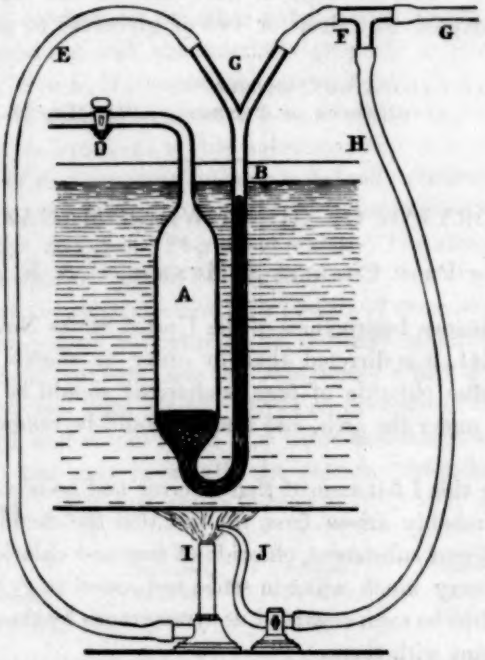
The instrument about to be described is adapted to maintain a constant temperature within any water or air chamber heated by gas, the degree of temperature thus maintained being adjustible at will.

Reference to the illustration shows an air thermometer so modified that the rise of mercury in the limb *B*, will cut off the gas supply which passes through its bifurcated extremity. A second modification lies in the accurately fitting glass stop-cock *D*, connected with the air chamber *A*. By means of this stop-cock the tension of the air within the chamber, and consequently the height of the mercury in the tube *B*, is readily adjustable. It is evident that when the mercury is forced high up in *B*, a relatively slight increase in the temperature of the surrounding medium will be sufficient to so expand the air in *A* as to force the column of mercury to the point of shut-off. On the other hand, a far higher temperature will be needed to effect the shut-off when the columns of mercury in *A* and *B* are of the same height. In practice the adjustment is effected by placing the instrument in a medium of the required temperature, the cock *D* is opened, and air slowly forced in with a syringe, until the mercurial column in *B* is nearly at the point of bifurcation; the precise height varying, of course, with the dimensions of the instrument, and being readily ascertained by practice.

The pressure of the gas employed must be kept quite low, otherwise as the mercury rises above the point of bifurcation, a portion will be blown out. One of the simpler gas pressure regulators may be advantageously inserted between the source of gas supply and the heat

regulator. It is well also that the diameter of the limb *C* should be somewhat greater than that of its fellow, and also that its point of junction with *B* should be somewhat constricted in order that a smaller variation in temperature shall effect either the patency or occlusion of the gas exit.

When the mercury rises in *B* a trifle beyond the point of bifurcation, the passage of gas from *G* to *E* is arrested, and the flame from the burner *I*, is at once extinguished. Were no further provision made,



the vessel and its contents would soon cool sufficiently to again permit the flow of gas which would then pass off, unburnt, through *I*. This difficulty is obviated by the use of a second gas jet *J*, so placed as to relight the burner *I*, upon the renewed passage of gas, and so minute as not to give out sufficient heat to counterbalance that which is lost from the vessel by radiation, etc., during the temporary stoppage in the main jet. This secondary jet may be readily made from a common brass blow-pipe, bent in the form shown in *J*, and steadily supported in such manner that its little flame may constantly play immediately

above the opening of the main burner. It is usually necessary to still further reduce the small opening of the blow-pipe by squeezing it with pliers, or by other means. The secondary flame is fed by a branch *H*, from the source of gas supply.

The instrument must be protected from touching the base of the containing vessel either by suspension or by the intervention of a plate of cork or other non-conductor. It must also be held steadily vertical, and should always be accompanied by a thermometer to verify its adjustment. It is also well to have each of the exposed surfaces of mercury covered by a drop or two of glycerine to prevent oxidation.

BIOLOGICAL LABORATORY, OF THE
UNIVERSITY OF PENNSYLVANIA, May 29, 1884.

THE DRYING OF GUNPOWDER MAGAZINES.*

By PROF. CHARLES E. MUNROE, U. S. N. A.

In the Ordnance Instructions of the United States Navy, paragraph 1233, page 341, it is directed that, in order to absorb the moisture from a magazine, chloride of *lime* or charcoal should be suspended in an open box under the arch, and that it should be renewed from time to time.

On reading this I felt assured that an error had been committed, and that it had probably arisen from the fact that the chemical names of two quite different substances, chloride of *lime* and chloride of *calcium*, are really so very much alike in sense and sound as to be very often confused, and to be even regarded as synonymous by those who are not quite conversant with them.

Chloride of *lime* is the substance which is sold in commerce under the name of bleaching powder, and it is believed to generally consist of a mixture of CaO, CaH_2O_2, $CaCl_2$ and $Ca(ClO)_2$ or $(CaO)Cl_2$. When charged as completely as possible with Cl and when in its purest form it is regarded by Kolbe† as having the composition represented by $Ca_3H_6O_6Cl_4$, which by the action of water is decomposed as follows:

$$Ca_3H_6O_6Cl_4 = CaH_2O_2 + CaCl_2 + Ca(ClO)_2 + 2H_2O.$$

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* U. S. Nav. Inst. Proc. Vol. ix.
† Ann. Ch. Phys. [4], 12, 266.

When exposed to the air the bleaching powder absorbs water, probably in proportion to the $CaCl_2$ and CaO which it contains, but it is not regarded as a deliquescent salt. At the same time it absorbs CO_2 from the atmosphere, and the calcium hypochlorite is decomposed, probably in accordance with the reaction

$$Ca(ClO)_2+H_2O+CO_2=CaCO_3+2HClO$$

or

$$Ca(ClO)_2+H_2O+CO_2=CaCO_3+H_2O+Cl_2+O.$$

Chloride of *calcium*, on the other hand, has the formula $CaCl_2$. Its most distinguishing and characteristic property is that it is highly deliquescent; that is, it possesses the power of absorbing moisture from the atmosphere, when it is exposed to it, to such a degree as to become a liquid. So deliquescent is this substance that it is always used as the example of that property when it is defined. Brandes* found that 100 parts of it, exposed to an atmosphere saturated with moisture for ninety-six days, absorbed 124 parts of water. The atmosphere has no further effect upon it than to liquefy it.

To compare the relative absorptive powers of these two substances, I exposed watch-glasses, containing, one, ordinary bleaching powder, the other chloride of calcium, side by side under a bell glass in which a vessel of water had been placed. After an exposure of three days they were weighed, and it was found that while the bleaching powder had gained 30·70 per cent. in weight, the calcium chloride had increased 60·50 per cent. The data are as follows:

	Wt. taken. Grams.	Wt. found. Grams.	Increase. Grams.	Per cent.
Calcium chloride	22·2724	36·0195	13·7471	60·50
Bleaching powder	32·9250	43·0380	10·1130	30·70

The conditions of the experiment were quite favorable to absorption of moisture by the bleaching powder, for there was necessarily but a limited supply of CO_2 in the bell glass. When it is exposed to the air the CO_2 which it absorbs forms a crust of $CaCO_3$ over its surface, which impedes the absorption of moisture.

From the consideration, then, of the hygroscopic properties of these two substances it is evident that it is the chloride of *calcium* and not the chloride of *lime* which should be used as a desiccating agent for magazines, and as it is a by-product which is obtained in enormous

* Schw. 51, 433, and Watts Dict. Chem. 1, 716.

quantities in the manufacture of soda, it ought to be obtained very cheaply. The porous chloride which has been dried at about 200° C. is better adapted for absorbing water than the fused chloride, since the latter contains both CaO and $CaCO_3$ as a result of igniting the chloride in contact with air.

In addition to the fact that bleaching powder is not the most efficient desiccating agent, either as regards its power or its price, it has occurred to me that, owing to certain other properties which it possesses, it might prove to be a very objectionable substance for use for this purpose.

It is known that after gunpowder has been stored for some time its initial velocity is reduced. This is held to be due to the absorption of moisture and the consequent efflorescence of the nitre. While recognizing the force of this explanation, I have surmised that there are other causes for this deterioration, and that one of them might be found in the slow oxidation of the sulphur, its conversion into sulphuric acid, the decomposition of the nitre with the formation of potassium sulphate and nitric acid, and then the further oxidation of sulphur by this nitric acid. The potassium sulphate thus formed would act, like the glass in Gale's process, or the graphite, charcoal, and so on, of Piobert and Fadéieff, for gunpowder; the silica in use for the silicated gun-cotton, or the camphor in the gum dynamite, to reduce the rate of inflammation, or of the transmission of the explosive undulations. The most satisfactory way for testing this theory would be by examining samples of fresh gunpowder for sulphuric acid, and then, after it had been exposed for some years to the incidents of storage and transportation which obtain in the service, to examine the same lot of powder again. I have not as yet had an opportunity for putting the theory to the test.

It, however, seemed probable to me that if oxidation, of the nature spoken of, could take place in the presence of air and moisture only, it would certainly be hastened by the presence of bleaching powder, since when the latter is exposed to the air the CO_2 absorbed decomposes it in accordance with the reactions given above by which chlorine or oxides of chlorine are liberated. These products in the presence of water are powerful oxidizing agents and will consequently act more energetically than the oxygen of the air alone. To test this I arranged an apparatus so that washed CO_2 might pass into a bottle in which bleaching powder suspended in water was placed, and the washed pro-

duct of this reaction was passed into a flask in which the gunpowder to be tested was suspended in water. The gunpowder taken for the test was Oriental.

Two portions of this powder were weighed, each being placed in a separate flask, and 200 cm. of distilled water added to it. Through one of these the gas from the bleaching powder was allowed to bubble for twelve hours and then it remained standing for some time. It was exposed to the action of the gas in all for thirty-six hours, most of the time being in strong daylight. The other flask stood, uncorked, for the same time in another room. Both were now filtered and 100 cm. of each were taken and treated with hydrochloric acid and barium chloride. The precipitate obtained in each case was washed and ignited as for the determination of sulphuric acid. The results were as follows:

	Wt. taken. grams.	Wt. $BaSO_4$ fd. grams.	Per cent. S oxidized.
Samples exposed to air,	3·4070	.....	0·16
" " " bleaching powder,	4·0692	·4768	1·60

That is, that in the sample of gunpowder exposed to the bleaching powder, there was ten times as much sulphur oxidized as in that which was exposed to the air.

The method of experiment described above was employed because it was known that the state of solution would favor the change, and it was supposed that, under the conditions which prevail in magazines, a marked change would not be noticed except after a considerable length of time. However, an experiment was set on foot which imitated the conditions exactly. I put a quantity of bleaching powder in the bottom of a desiccator, and on the shelf above I put a weighed quantity of the Oriental superfine saltpetre powder, in the granulated, glazed state in which it is sold. The desiccator was then covered and set aside. At the end of twenty-six days I examined the powder, and was surprised to see an appearance of change on the surface of the powder granules; so I immediately dissolved in hot water, filtered and precipitated with barium chloride and hydrochloric acid. For comparison, I made another determination of the sulphates in the fresh powder. The results are as follows:

	Wt. taken. grams.	Wt. $BaSO_4$ fd. grams.	Per cent. of S. oxidized.
Fresh powder,	6·6818	·0816	0·17
Powder exposed 26 days to atmosphere of bleaching powder,	6·0256	·6566	1·50

It would seem to follow, from the above results, that while the chloride of *lime* is not so efficient a desiccating agent as the chloride of *calcium*, it is at the same time very objectionable, since it *may* cause a serious deterioration of the gunpowder.

I purpose hereafter to examine samples of powder which have been acted upon by the gases from bleaching powder, by means of a method which I have recently devised for testing the incorporation of gunpowder, and I hope, before long, to have the honor of describing this method to you.

ON AN EXPLANATION OF HALL'S PHENOMENON.

By SHELFORD BIDWELL, M.A., LL.B.

[Abstract of a paper read at the meeting of the Royal Society, Feb. 21, 1884.]

Mr. E. H. Hall's papers giving a full account of his well-known discovery are printed in the *Philosophical Magazine* for March, 1880, November, 1880, September, 1881, and May, 1883. His original experiment was as follows: A strip of gold leaf was cemented to a plate of glass and placed between the poles of an electro-magnet, the plane of the glass being perpendicular to the magnetic lines of force. The current derived from a Bunsen cell was passed longitudinally through the gold, and, before the electro-magnet was excited, two equipotential points were found by trial near opposite edges of the gold-leaf, and about midway between the ends: when these points were connected with a galvanometer there was of course no deflection. A current from a powerful battery being passed through the coils of the magnet, it was found that a galvanometer deflection occurred, indicating a difference of potential between the two points, the direction of the current across the gold leaf being opposite to that in which the gold leaf itself would have moved across the lines of force had it been free to do so. On reversing the polarity of the magnet the direction of the transverse electromotive force was reversed, and when the magnet was demagnetized the two points reverted to their original equipotential condition.

Subsequent experiments showed that the direction of the effect differed according to the metal used. Thus with silver, tin, copper, brass, platinum, nickel, aluminium and magnesium the direction of

the transverse electromotive force was found to be the same as in the case of gold: with iron, cobalt and zinc the direction was reversed, and with lead there was no sensible effect in either direction.

Hall's results may be expressed by saying that the equipotential lines across the strip are rotated in a definite direction with respect to the lines of force. This effect was attributed by him to the direct action of the magnet on the current; and very great importance has been attached to the phenomenon in consequence of the opinion expressed by Professor Rowland and others that it is connected with the magnetic rotation of the plane of polarization of light, and thus furnishes additional evidence of an intimate relation between light and electricity.

A number of experiments made by the author convinced him, however, that no direct action of the kind supposed was ever produced, and he ultimately found that Hall's phenomenon might be completely explained by the joint action of mechanical strain and certain thermo-electric effects.

The strain is produced by electro-magnetic action. It will be convenient to refer to the metallic plate or strip (which for the purposes of this explanation may be assumed to be rectangular) as if it were an ordinary map, the two shorter sides being called respectively west and east, and the two longer north and south. Let the south pole of an electro-magnet be supposed to be beneath the strip, and let the strip be traversed by a current passing through it in a direction from west to east. Then the strip will tend to move across the lines of force in the direction from south to north. Since, however, it is not free to move bodily from its position, it will be strained, and the nature of the strain will be somewhat similar to that undergone by a horizontal beam of wood which is rigidly fixed at its two ends and supports a weight at the middle. Imagine the strip to be divided into two equal parts by a straight line joining the middle points of the west and east sides. Then in the upper or northern division the middle district will be stretched and the eastern and western districts will be compressed, while in the lower division the middle part will be compressed and the two ends will be stretched. If now a current is passing through the plate from west to east, the portion of the current which traverses the northern division will cross first from a district which is compressed to one which is stretched, and then from a district which is stretched to one which is compressed; while in the southern division

the converse will be the case. And here the thermo-electric effects above referred to come into play.

Sir William Thomson, in 1856, announced the fact that a stretched copper wire is thermo-electrically positive to an unstretched wire of the same metal, while a stretched iron wire is negative to an unstretched iron wire. From this it might be inferred, as Sir William Thomson remarks, that a free copper wire is positive to a longitudinally compressed copper wire, and that a free iron wire is negative to a longitudinally compressed iron wire; and experiment shows this to be the case. *A fortiori* therefore a stretched copper wire is thermo-electrically positive to a compressed copper wire, and a stretched iron wire is negative to a compressed iron wire. If, therefore, a current is passed from a stretched portion of a wire to a compressed portion, heat will (according to the laws of the Peltier effect) be absorbed at the junction if the metal is copper, and will be developed at the junction if the metal is iron. In passing from compressed to stretched portions the converse effects will occur.

It follows from the above considerations that if the metal plate (which is subjected to a stress from south to north and is traversed by a current from west to east) be of copper, heat will be developed in the western half of the northern division and absorbed in the eastern half; while heat will be absorbed in the western half of the southern division and developed in the eastern half. But the resistance of a metal increases with its temperature. The resistance of the northwestern and southeastern districts of the plate will therefore be greater, and that of the northeastern and southwestern districts smaller than before it was subjected to the stress; and an equipotential line through the centre of the plate, which would originally have been parallel to the west and east sides, will now be inclined to them, being apparently rotated in a counter-lock-wise direction.

If the plate were of iron instead of copper the Peltier effects would clearly be reversed, and the equipotential line would be rotated in the opposite direction.

The peculiar thermo-electric effects of copper and iron discovered by Thomson are thus seen to be sufficient to account for Hall's phenomenon in the case of those metals. It became exceedingly interesting to ascertain whether the above explanation admitted of general application, and the author therefore proceeded to repeat Thomson's experiments upon all the metals mentioned by Hall. The results are

given in the following table, where those metals which in Hall's experiments behave like gold are distinguished as negative, and those which behave like iron as positive.

TABLE.

S means stretched. U means unstretched.

Metals.	Forms used.	Direction of current.	Hall's effect.
Copper	Wire and foil, pure	S. to U.	Negative
Iron	Wire and sheet, annealed	U. to S.	Positive
Brass	Wire, commercial	S. to U.	Negative
Zinc	Wire and foil	U. to S.	Positive
Nickel	Wire	S. to U.	Negative
Platinum	Wire and foil	S. to U.	Negative
Gold	Foil, purity 9·99 per cent.	S. to U.	Negative
	Wire, commercially pure	*U. to S.*	
	Jeweller's 18 ct. wire and sheet	S. to U.	
	Jeweller's 15 ct. sheet	S. to U.	
Silver	Wire and foil	S. to U.	Negative
Aluminium	*Wire and foil, pure*	*U. to S.*	*Negative?*
Cobalt	Rod, 8 mm. diameter	U. to S.	Positive
Magnesium	Ribbon	S. to U.	Negative
Tin	Foil	S. to U.	Negative
Lead	Foil (assay)	No current.	Nil

It will be seen that in every case excepting that of aluminium and one out of five specimens of gold there is perfect correspondence between the direction of the thermo-electric current and the sign of Hall's effect. With regard to the aluminium, a piece of the foil was mounted on glass and Hall's experiment performed with it. As was anticipated, the sign of the "rotational coefficient" was found to be positive, like that of iron, zinc and cobalt. Either, therefore, Mr. Hall fell into some error, or the aluminium with which he worked differed in some respect from that used by the author. The anomalous specimen of gold, being in the form of wire, could not be submitted to the same test. It probably contained some disturbing impurity.

It is submitted that the considerations and experiments above

detailed render it abundantly evident that the phenomenon described by Mr. Hall involves no new law of nature, but is merely a consequence of certain thermo-electric effects which had been observed nearly thirty years ago

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INSTRUCTION IN MECHANICAL ENGINEERING.

By Professor R. H. Thurston.

The writer has often been asked by correspondents interested in the matter of technical and trade education to outline a course of instruction in mechanical engineering, such as would represent his idea of a tolerably complete system of preparation for entrance into practice. The synopsis given at the end of this article was prepared in the spring of 1871, when the writer was on the U. S. Naval Academy, as Assistant Professor of Natural and Experimental Philosophy, and, being printed, was submitted to nearly all of the then leading mechanical engineers of the United States, for criticism, and with a request that they would suggest such alterations and improvements as might seem to them best. The results was general approval of the course, substantially as here written. This outline was soon after proposed as a basis for the course of instruction adopted at the Stevens Institute of Technology, at Hoboken, to which institution the writer was, at about that time, called. He takes pleasure in accepting a suggestion that its publication in the Journal would be of some advantage to many who are interested in the subject.

The course here sketched, as will be evident on examination, includes not only the usual preparatory studies pursued in schools of mechanical engineering, but also advanced courses, such as can be taught in special schools only, and only there when an unusual amount of time can be given to the professional branches, or when post-graduate courses can be given, supplementary to the general course. The complete course, as here planned, is not taught in any existing school, so far as the writer is aware. In his own lecture room, the principal subjects, and especially those of the first part of the work, are presented with tolerable thoroughness; but many of the less essential portions are necessarily greatly abridged. As time can be found for the extension of the course, and as students come forward better prepared for their

work, the earlier part of the subject is more and more completely developed, and the advanced portions are taken up in greater and greater detail, each year giving opportunity to advance beyond the limits set during the preceding year.

Some parts of this scheme are evidently introductory to advanced courses of study which are to be taken up by specialists, each one being adapted to the special instruction of a class of students who, while pursuing it, do not usually take up the other and parallel courses. Thus, a course of instruction in Railroad Engineering, a course in Marine Engineering, or a course of study in the engineering of textile manufactures, may be arranged to follow the general course, and the student will enter upon one or another of these advanced courses as his talents, interests, or personal inclinations may dictate. At the Stevens Institute of Technology, two such courses—Electrical and Marine Engineering—are now organized as supplementary of the general course, and are pursued by all students taking the degree of Mechanical Engineer. These courses, as there given, however, are not fairly representative of the idea of the writer, as above expressed, since the time available in general course is far too limited to permit them to be developed beyond the elements, or to be made, in the true sense of the term, advanced professional courses. Such advanced courses as the writer has proposed must be far more extended, and should occupy the whole attention of the student for the time. Such courses should be given in separate departments under the direction of a General Director of the professional courses, who should be competent to determine the extent of each, and to prevent the encroachment of the one upon another; but they should each be under the immediate change of a specialist capable of giving instruction in the branch assigned to him, in both the theoretical and purely scientific, and the practical and constructive sides of the work. Every such school should be organized in such a manner that one mind, familiar with the theory and the practice of the professional branches taught, should be charged with the duty of giving general direction to the policy of the institution and of directing the several lines of work confided to specialists in the different departments. It is only by careful and complete organization in this, as in every business, that the best work can be done at least expense in time and capital.

In this course of instruction in Mechanical Engineering, it will be observed that the writer has incorporated the scheme of a workshop

course. This is done, not at all with the idea that a school of mechanical engineering is to be regarded as a "trade school," but that every engineer should have some acquaintance with the tools and the methods of work upon which the success of his own work is so largely dependent. If the mechanical engineer can acquire such knowledge in the more complete course of instruction of the trade school, either before or after his attendance at the technical school, it will be greatly to his advantage. The technical school has, however, a distinct field; and its province is not to be confounded with that of the trade school. The former is devoted to instruction in the theory and practice of a profession which calls for service upon the men from the latter—which makes demand upon a hundred trades—in the prosecution of its designs. The latter teaches, simply, the practical methods of either of the trades subsidiary to the several branches of engineering, with only so much of science as is essential to the intelligent use of the tools and the successful application of the methods of work of the trade taught. The distinction between the two departments of education, both of which are of comparatively modern date, is not always appreciated in the United States, although always observed in those countries of Europe in which technical and trade education have been longest pursued as essential branches of popular instruction. Throughout France and Germany, every large town has its trade schools, in which the trades most generally pursued in the place are systematically taught; and every large city has its technical school, in which the several professions allied to engineering are studied, with special development of those to which the conditions prevailing at the place give most prominence and local importance.

A course of trade instruction, as the writer would organize it, would consist, first, in the teaching of the apprentice the use of the tools of his trade, the nature of its materials, and the construction and operation of the machinery employed in its prosecution. He would next be taught how to shape the simpler geometrical forms in the materials of his trade, getting out a straight prism, a cylinder, a pyramid, or a sphere, of such size and form as may be convenient; getting lines and planes at right angles, or working to miter, practicing the working of his "job" to definite size, and to the forms given by drawings, which drawings should be made by the apprentice himself. When he is able to do good work of this kind, he should attempt larger work, and the construction of parts of structures involving exact fitting and

special manipulations. The course, finally, should conclude with exercises in the construction and erection of complete structures and in the making of peculiar details, such as are regarded by the average workman as remarkable "*tours de force.*" The trade school usually gives instruction in the common school branches of education, and especially in drawing, free-hand and mechanical, carrying them as far as the successful prosecution of the trade requires. The higher mathematics, and advanced courses in physics and chemistry, always taught in schools of engineering, are not taught in the trade school, as a rule; although introduced into those larger schools of this class in which the aim is to train managers and proprietors, as well as workmen. This is done in many European schools.

As is seen above, the course of instruction in mechanical engineering includes some trade education. The engineer is dependent upon the machinist, the founder, the pattern-maker, and other workers at the trades, for the proper construction of the machinery and structures designed by him. He is himself, in so far as he is an engineer, a designer of constructions, not a constructor. He often combines, however, the functions of the engineer, the builder, the manufacturer, and the dealer, in his own person. No man can carry on, successfully, any business in which he is not at home in every detail, and in which he cannot instruct every subordinate, and cannot show every person employed by him precisely what is wanted, and how the desired result can be best attained. The engineer must, therefore, learn, as soon and as thoroughly as possible, enough of the details of every art and trade, subsidiary to his own department of engineering, to enable him to direct, with intelligence and confidence, every operation that contributes to the success of his work. The school of engineering should therefore be so organized that the young engineer may be taught the elements of every trade which is likely to find important application in his professional work. It cannot be expected that time can be given him to make himself an expert workman, or to acquire the special knowledge of details and the thousand and one useful devices which are an important part of the stock in trade of the skilled workman; but he may very quickly learn enough to facilitate his own work greatly, and to enable him to learn still more, with rapidity and ease, during his later professional life. He must also, usually, learn the essential elements and principles of each of several trades, and must study their relations to his work, and the limitations of his methods

of design and construction which they always, to a greater or less extent, cause by their own practical or economical limitations. He will find that his designs, his methods of construction, and of fitting up and erecting, must always be planned with an intelligent regard to the exigencies of the shop, as well as to the aspect of the commercial side of every operation. This extension of trade education for the engineer into several trades, instead of its restriction to a single trade, as is the case in the regular trade school, still further limits the range of his instruction in each. With unusual talent for manipulation, he may acquire considerable knowledge of all the subsidiary trades in a wonderfully short space of time, if he is carefully handled by his instructors, who must evidently be experts, each in his own trade. Even the average man who goes into such schools, following his natural bent, may do well in the shop course, under good arrangements as to time and character of instruction. If a man has not a natural inclination for the business, and a natural aptitude for it, he will make a great mistake if he goes into such a school with the hope of doing creditable work, or of later attaining any desirable position in the profession.

The course of instruction, at the Stevens Institute of Technology, includes instruction in the trades to the extent above indicated. The original plan, as given below, included such a course of trade education for the engineer; but it was not at once introduced. The funds available from an endowment fund crippled by the levying of an enormous "succession tax" by the United States government, and by the cost of needed apparatus and of unanticipated expenses in buildings and in organization, were insufficient to permit the complete organization of this department. A few tools were gathered together; but skilled mechanics could not be employed to take up the work of instruction in the several courses. Little could therefore be done for several years in this direction. In 1875 the writer organized a "Mechanical Laboratory," with the purpose of attaining several very important objects viz.: The prosecution of scientific research in the various departments of engineering work; the creation of an organization that should give students an opportunity to learn the methods of research most usefully employed in such investigations; the assistance of members of the profession, and business organizations, in the attempt to solve such questions, involving scientific research, as are continually arising in the course of business; the employment of students who

had done good work in their college course, when they so desire, in work of investigation, with a view to giving them such knowledge of this peculiar line of work as should make them capable of directing such operations elsewhere; and finally, but not least important of all, to secure, by earning money in commercial work of this kind, the funds needed to carry on those departments of the course in engineering that had been, up to that time, less thoroughly organized than seemed desirable. This "laboratory" was organized in 1875, the funds needed being obtained by drawing upon loans offered by friends of the movement and by the "Director."

It was not until the year 1878, therefore, that it became possible to attempt the organization of the shop course; and it was then only by the writer assuming personal responsibility for its expenses that the plan could be entered upon. As then organized—in the autum of 1878—a superintendent of the workshop had general direction of the trade department of the school. He was instructed to submit to the writer plans, in detail, for a regular course of shop instruction, and was given as assistant a skilled mechanic of unusual experience and ability, whose compensation was paid from the mechanical laboratory funds, and guaranteed by the writer personally, and another aid whose services were paid for partly by the Institute and partly as above. The pay of the superintendent was similarly assured. This scheme had been barely entered upon when the illness of the writer compelled him to temporarily give up his work, and the direction of the new organization fell into other hands, although the department was carried on, as above, for a year or more after this event occured.

The plan did not fall through; the course of instruction was incorporated into the college course, and its success was finally assured by the growth of the school and a corresponding growth of its income, and, especially, by the liberality of President Morton, who met expenses to the amount of many thousands of dollars by drawing upon his own bank account. The department was by him completely organized, with an energetic head, and needed support was given, in funds and by a force of skilled instructors. This school is now in successful operation. This course now also includes the systematic instruction of students in experimental work, and the objects sought by the writer in the creation of a "mechanical laboratory" are thus more fully attained than they could have possibly been otherwise. It is to be hoped that, at some future time, when the splendid bequest of Mr.

Stevens may be supplemented by gifts from other equally philanthropic and intelligent friends of technical education, among the alumni of the school and others, this germ of a trade school may be developed into a complete institution for instruction in the arts and trades of engineering, and may thus be rendered vastly more useful by meeting the great want, in this locality, of a real trade school, as well as fill the requirements of the establishment of which it forms a part, by giving such trade education as the engineer needs, and can get time to acquire.

The establishment of advanced courses of special instruction in the principal branches of mechanical engineering may, if properly "dovetailed" into the organization, be made a means of somewhat relieving the pressure that must be expected to be felt in the attempt to carry out such a course as is outlined below. The post-graduate or other special departments of instruction, in which, for example, railroad engineering, marine engineering, and the engineering of cotton, woolen, or silk manufactures, are to be taught, may be so organized that some of the lectures of the general course may be transferred to them, and the instructors in the latter course thus relieved, while the subject so taught, being treated by specialists, may be developed more efficiently and more economically.*

Outlines of these advanced courses, as well as of the courses in trade instruction comprehended in the full scheme of mechanical engineering courses laid out by the writer a dozen years ago, and as since recast, might be here given, but their presentation would occupy too much space, and they are for the present omitted.

The course of instruction in this branch of engineering, at the Stevens Institute of Technology, is supplemented by "Inspection Tours," which are undertaken by the graduating class toward the close of the last year, under the guidance of their instructors, in which expeditions they make the round of the leading shops in the country, within a radius of several hundred miles, often, and thus get an idea of what is meant by real business, and obtain some notion of the extent of the field of work into which they are about to enter, as well as of the importance of that work and the standing of their profession among the others of the learned professions with which that of engineering has now come to be classed.

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* The workshop course may be similarly relieved by the preparatory training of younger boys, who may be taught the use of tools before entering the higher schools.

At the close of the course of instruction, as originally proposed, and as now carried out, the student prepares a "graduating thesis," in which he is expected to show good evidence that he has profited well by the opportunities which have been given him to secure a good professional education. These theses are papers of, usually, considerable extent, and are written upon subjects chosen by the student himself, either with or without consultation with the instructor. The most valuable of these productions are those which present the results of original investigations of problems arising in practice or scientific research in lines bearing upon the work of the engineer. In many cases, the work thus done has been found to be of very great value, supplying information greatly needed in certain departments, and which had previously been entirely wanting, or only partially and unsatisfactorily given by authorities. Other theses of great value present a systematic outline of existing knowledge of some subject which had never before been brought into useful form, or made in any way accessible to the practitioner. In nearly all cases, the student is led to make the investigation by the bent of his own mind, or by the desire to do work that may be of service to him in the practice of his profession.* All theses are expected to be made complete and satisfactory to the head of department of engineering before his signature is appended to the diploma which is finally issued to the graduating student. These preliminaries being completed, and the examinations having been reported as in all respects satisfactory, the degree of Mechanical Engineer is conferred upon the aspirant, and he is thus formally inducted into the ranks of the profession.

COURSE OF INSTRUCTION IN MECHANICAL ENGINEERING.
Robert H. Thurston—July, 1871.

I.

MATERIALS USED IN ENGINEERING.—Classification, Origin, and Preparation (where not given in course of Technical Chemistry), Uses, Cost.
Strength and Elasticity.—Theory (with experimental illustrations), reviewed, and tensile, transverse and torsional resistance determined.
Forms of greatest strength determined. *Testing* materials.
Applications.—Foundations, Framing in wood and metal.
FRICTION.—Discussion from Rational Mechanics, reviewed and extended.
Lubricants treated with materials above.
Experimental determination of "coefficients of friction."

* Some of these papers have been published in the JOURNAL OF THE FRANKLIN INSTITUTE, and other periodicals, as valuable contributions to technical literature.

II.

TOOLS.—Forms for working wood and metals. Principles involved in their use.

Principles of pattern making, moulding, smith and machinists' work so far as they modify design.

Exercises in Workshop in mechanical manipulation.

Estimates of cost (stock and labor).

MACHINERY AND MILL WORK.—Theory of machines. Construction. Kinematics applied. Stresses, calculated and traced. Work of machines. Selection of materials for the several parts. Determination of *proportions* of details, and of *forms* as modified by difficulties of construction.

Regulators, Dynamometers, Pneumatic and Hydraulic machinery. Determining *moduli* of machines.

POWER, transmission by gearing, belting, water, compressed air, etc.

LOADS, transportation.

III.

HISTORY AND PRESENT FORMS OF THE PRIME MOVERS.

Windmills, their theory, construction, and application.

Water Wheels. Theory, construction, application, testing, and comparison of principal types.

Air, Gas, and Electric Engines, similarly treated.

STEAM ENGINES.—Classification. [Marine (merchant) Engine assumed as representative type.] Theory. Construction, including general design, form and proportion of details.

Boilers similarly considered. Estimates of cost.

Comparison of principal types of Engines and Boilers.

Management and repairing. Testing and recording performance.

IV.

MOTORS APPLIED TO MILLS. Estimation of required power and of cost.

Railroads. Study of Railroad machinery.

Ships. Structure of Iron Ships and Rudiments of Naval Architecture and Ship Propulsion.

PLANNING Machine shops, Boiler shops, Foundries, and manufactories of textile fabrics. Estimating cost.

LECTURES BY EXPERTS.

GENERAL SUMMARY of principal facts, and natural laws, upon the thorough knowledge of which successful practice is based; and general *resumé* of principles of business which must be familiar to the practicing engineer.

V.

GRADUATING THESES.

GRADUATION.

Accompanying the above, are courses of instruction in higher mathematics, graphics, physics, chemistry, and the modern languages and literatures.

REPORT ON THE TRIAL OF THE "CITY OF FALL RIVER."

By J. E. SAGUE, M. E., and J. B. ADGER, M. E., with an introduction by Professor R. H. THURSTON.

(Concluded from vol. cxviii., page 115.)

COAL CONSUMPTION.

As above shown it was impossible to make an exact boiler test, and it was therefore impossible to get an exact figure for the number of pounds of coal per horse power per hour used by the engine.

It was at first supposed by the authors that it would be perfectly fair, for the engine, to assume that the fire was the same at Throggs Neck, as it was on leaving Fall River, *i.e.*, that there was the same depth of coal on the grate and the same porportion of ashes in this depth. It was thought that this assumption would give the closest appoximation possible and a very nearly correct figure. Upon examination however it was found that a difference of four inches in the depth would make a difference in the weight of coal per horse power per hour of about ¼ pound. When one considers the heat and glare to which the eye was exposed on opening the furnace door, the fire being nearly white hot, the probability of one's being able to judge within three or four inches of the comparative depths of the two fires becomes very small. Then, too, the assumption that the proportion of ash on the grate at the start, from the bank, and the 3,000 or 4,000 pounds of coal thrown on within two hours of starting, is the same as after the fire has been burning fiercely for nine or ten hours, even though the fire has been sliced once or twice, admits of too great an error to carry conviction. The above assumption therefore could not be supported and that method of obtaining a figure for the coal consumption of the engine had to be abandoned.

The most closely approximate figure must be obtained from the boiler test, as follows. The average actual evaporation of the two boilers is divided into the number of pounds of water used by the engine per horse power per hour. For example, on the night of May 10th, the number of pounds of water evaporated from the temperature of the feed in the forward boiler was 7·939 pounds, and in the after boiler 8·156 pounds, average 8·047 pounds. The water per horse-

power per hour, obtained from the meters, was 17·173 pounds; dividing this by 8·047, we obtain 2·13 pounds for the coal per horse-power per hour. This of course may contain a slight error dne to the assumptions made as above; but, we think that it is an outside figure, and consequently a safe one, and may be taken as practically correct.

The same figure for the other nights will be found in the table below. The amount of coal used per day on the regular trips, which may be called the commercial coal figure, was obtained very exactly, and this is the figure which specially interests the owners. For the sake of having a figure convenient in comparisons, we shall divide by the number of hours the engine was actually running on each day and also by the number of horse-power developed, getting thus the number of pounds of coal per horse-power per hour.

This commercial coal figure was gotten both when the compound engine was running and also after the high pressure cylinder was thrown off and the engine was run as a simple engine with only the large cylinder of the engine connected. In the latter case however the commercial coal figure is not strictly exact, but is closely approxinate. This commercial figure includes all the coal used per day; that used in the banks and getting up steam as well as that actually evaporating the water while the boat is under way.

	B	C	D	E
Date of experiment	May 4	May 9	May 10	June 7
Average temperature of chimney gases	460°	440°	455°	612°
No. of pounds of coal used by engine, per indicated horse-power per hour	2·045	2·09	2·13	
No. of pounds of combustible used by engine per indicated horse-power per hour	1·68	1·737	* 1·755	
Total No. of pounds of coal used by engine per indicated horse-power per hour	2·21	2·28	2·34	3·477

From the figures in the above table it is seen that the *City of Fall River* running with her compound engine, burns about 2·3 pounds of coal per horse-power per hour; while, when run, without her high pressure cylinder, as a simple engine, she requires 3·477 pounds of coal. The difference is 1·177 pounds per horse-power per hour, or running 11 hours a day and developing 1·600 horse-power the differ-

ence is very nearly 10 tons of coal a day, or 20 tons a round trip. That this difference cannot be attributed wholly to the engine is shown by the fact that the temperature in the chimney is much higher when the simple engine is used, and that therefore the efficiency of the boilers is materially decreased on account of their being very much forced to furnish the steam required by the simple engine as it was run upon June 7th.

RESULTS OF ENGINE TESTS.

The appended table contains the data and results of the tests made upon the engines. Most of the figures are sufficiciently explained in the table and only such as are the result of computation will be discussed here.

The columns designated with the first five letters of the Alphabet. A, B, C and D are the tests of the compound engine, and E was made after the high pressure cylinder had been disconnected and while the engine was running as a simple engine. The date of each test is prefixed to its appropriate column. The various pressures, temperatures, etc., are the average figures for the pressures, temperatures, etc., during the test and are obtained from numerous observations made at regular intervals. The fraction of stroke completed when the steam is cut off is found for each cylinder by taking on the cards the point of cut-off, and finding the average distance from this point back to the commencement of stroke. This distance is then divided by the average length of the cards and the quotient is the "fraction" sought. This is done for both the effective point of cut-off, which is the point of intersection of the admission line and the expansion line both prolonged, and is the point at which cut-off would take place if there were no wire-drawing, and also for the point of virtual cut-off, which is the point on the cards at which admission closes.

The number of revolutions per minute is the average figure, taken from the cards, upon each of which was carefully noted the number of revolutions the engine was making at the time the card was taken.

The indicated pressure on the piston at the various parts of the stroke were found from the indicator cards. The back pressure against the piston at the commencement of stroke is the pressure in the clearance spaces; and this is found, as the others are, from the cards, the point at which compression ceases being noted on them.

The mean effective pressure is found from the cards by dividing

the mean area, found with a carefully tested planimeter, by the mean length, and multiplying the quotient by the scale of the spring used in the indicator.

The mean back pressure during the stroke is found from the cards, by dividing the mean area between the back pressure line and the line of perfect vacuum by the mean length of the cards.

The horse-power is found for the top and bottom of each cylinder separately, and the area of the piston rod is deducted from the area acted upon by the steam in the case of the top of each cylinder.

The number of pounds of feed water consumed per horse-power per hour is found by the meters, the dial readings giving the number of cubic feet passed into the boiler during the test. From the meter tests, described above, the exact weight of each cubic foot was found; and the total number of pounds divided by the length of test in hours and by the horse-power developed by the engine gives the figures entered in the table.

The number of Fahr. heat-units consumed per hour per horse-power developed by the engine is found by getting the number of heat units absorbed by each pound of water, *i.e.*, by subtracting the temperature of the feed water from the total number of thermal units contained in one pound of steam at boiler pressure, and multiplying this difference by the number of pounds of water consumed per hour per indicated horse-power.

The number of times the steam was expanded is found for the compound engine by dividing the volume of the low pressure cylinder, plus the clearance spaces at one end, by the volume of the high pressure cylinder up to the point of effective cut-off, plus the clearance spaces of the high pressure cylinder at one end.

For the simple engine the volume of the cylinder, plus the clearance space of one end, is divided by the volume of the cylinder up to the point of cut-off, plus the clearance space at one end.

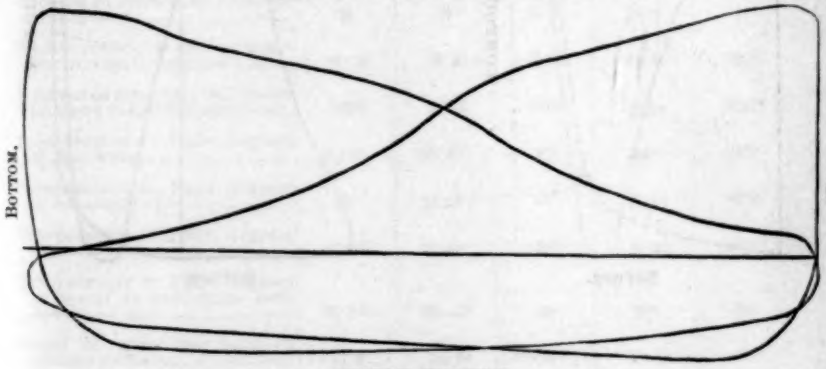
The number of pounds of steam accounted for by the indicator per hour per horse-power, at any point in the stroke, is found as follows:

The volume displaced by the piston up to the given point is added to the volume in clearance and steam passage at one end, and the sum multiplied by the weight of the unit of volume of steam at the pressure corresponding to the given point. From this product is deducted the weight of steam already present in the clearance space at one end at the commencement of stroke, using the weight of a unit of volume

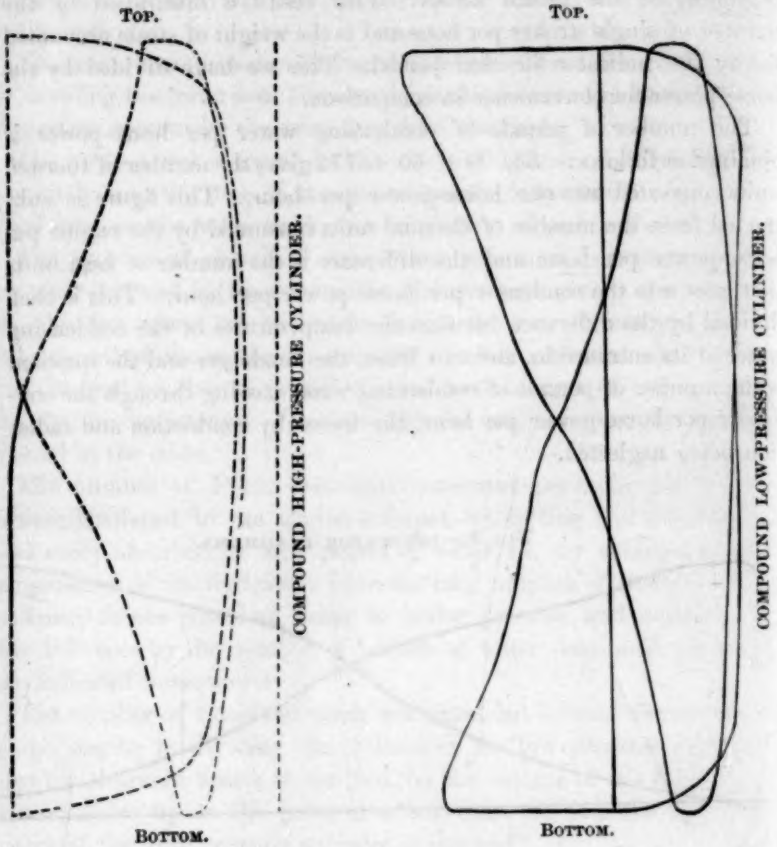
of steam of the pressure at the end of compression or just at the beginning of the return stroke. This result is multiplied by the number of single strokes per hour and is the weight of steam accounted for by the indicator for that period. This we have divided by the horse-power for convenience in comparison.

The number of pounds of condensing water per horse-power is obtained as follows: 33,000 × 60 ÷ 772 gives the number of thermal units converted into one horse-power per hour. This figure is subtracted from the number of thermal units consumed by the engine per horse-power per hour and the difference is the number of heat units that goes into the condenser per horse-power per hour. This is then divided by the difference between the temperatures of the condensing water at its entrance to, and exit from, the condenser and the quotient is the number of pounds of condensing water passing through the condenser per horse-power per hour, the losses by conduction and radiation being neglected.

FIG. 3.—INDICATOR DIAGRAMS.



SIMPLE ENGINE.


Top.
Bottom.
Compound High-Pressure Cylinder.
Top.
Bottom.
Compound Low-Pressure Cylinder.

RESULTS OF TRIALS OF THE "CITY OF FALL RIVER."

	A	B	C	D	E
Date of Test.	May 3	May 4	May 9	May 10	June 7
Mean steam pressure in boiler per guage	68·5	69	70	70	28·5
Mean steam pressure in receiver per guage	10	10·5	11	11	
Position of throttle valve	Open wide	Open wide	Open wide	Open wide	Open ⅞ths
Fraction of stroke in small cylinder completed before point of effective cut-off	.....	.....	.....	·445	
Fraction of stroke in small cylinder completed at point of virtual cut-off	.....	.....	.....	·548	
Fraction of stroke in large cylinder completed at point of virtual cut-off	.....	.....	.....	·488	·445
Number of times steam was expanded	.....	.....	.....	6·989	2·168
Height of barometer in inches of mercury	30·54	30·7	30·7	30·5	30·37
Vacuum in condenser in inches of mercury	28	28	28·6	28·4	27
Number of double strokes made per minute by pistons	28·53	25·91	25·53	25·71	23.87
Number of pounds of feed water pumped into boilers per hour.	26696	27718	27834	27854	35271
Temperature in Fahr. degrees of feed water	104·2°	101·65°	97°	97°	111°
Temperature in Fahr. degrees of atmosphere	82°	74·6°	78°	77·5°	82·4°
Temperature in Fahr. degrees of sea water	47·25°	47·64°	49°	49·38	50·22°
Temperature in Fahr. degrees of water at exit from condenser	95·57°	92·48°	89°	90°	104
Speed of vessel per hour in statute miles	17·5	15·94	16	17·3	15
Slip of centre pressure of wheels in per centum of speed according to Rankine's rules	10·2	.....	20·4	.....	
Mean draft of vessel	10′ 7″	10′ 5″	10′ 7″	10′ 65″	10′ 6″
Displacement at draft (gross tons)	1948	1908	1948	1908	1928
Indicated pressures on piston of small cylinder in lbs. per sq. in. above zero.					
Indicated at commencement of stroke	.....	.....	.....	82	
Indicated at point of virtual cut-off	.....	.....	.....	74·3	

RESULTS OF TRIALS OF THE "CITY OF FALL RIVER."—*Continued.*

	A	B	C	D	E
Date of test.	May 3	May 4	May 9	May 10	June 7
Indicated at end of stroke	.....	.....	.....	42·675	
Back pressure against piston of small cylinder at commencement of stroke in lbs. per sq. in. above zero	.....	.....	.....	75·125	
Indicated pressure on piston of small cylinder in lbs. per sq. in. (mean effective)	40·7	841·16	41·28	41·76	
Indicated pressures on piston of large cylinder in lbs. per sq. in. above zero	.....	.....	.....	.....	
Indicated at point of virtual cut-off	.....	.....	.....	17·416	28·66
Indicated at end of stroke	.....	.....	.....	0·47	14·74
Mean back pressure against the piston of large cylinder during stroke in lbs. per sq. in above zero	.....	.....	.....	4·89	
Back pressure against piston of large cylinder at commencement of stroke in lbs. per sq. in. above zero	.....	.....	.....	12·904	17·3
Indicated pressure on piston of large cylinder in lbs. per sq. in. (mean effective)	12·24	12·309	12·56	12·43	21·6
Indicated horse-power developed in small cylinder (top)	361·84	370·51	362·45	389·735	
Indicated horse-power developed in small cylinder (bottom)	396·52	407·45	406·33	413·18	
Indicated horse-power developed in large cylinder (top)	423·04	340·09	433·46	432·046	652·13
Indicated horse-power developed in large cylinder (bottom)	396·90	407·28	408·9	407·061	694·85
Aggregate indicated horse-power developed by engine	1578	1615	1611	1622	1347
Number of lbs. of feed water consumed per hour per indicated horse-power	16·972	17·157	17.276	17·173	16·185
Number of Fahr. heat units consumed per hour per indicated horse-power	18690	19005	19211	19090	28405
Weight of steam in lbs. per hour in small cylinder.					
Weight calculated from pressure at point of virtual cut-off	.....	.....	.....	25076	
Weight calculated from pressure at end of stroke	.....	.....	.....	25676	
Weight of steam in lbs. per hour in large cylinder.					
Weight calculated from pressure at point of virtual cut-off	.....	.....	.....	20697	31224·75
Weight calculated from pressure at end of stroke	.....	.....	.....	22421	31798·74

RESULTS OF TRIALS OF THE "CITY OF FALL RIVER."—*Continued.*

	A	B	C	D	E
Date of test.	May 3	May 4	May 9	May 10	June 7
Weight of steam in lbs. per indicated horse-power per hour.					
Weight in small cylinder at point of cut-off (virtual)	.....	.....	.....	15·46	
Weight in small cylinder at point of release	.....	.....	.....	15·83	
Weight of steam in lbs. per indicated horse-power per hour.					
Weight in large cylinder at point of virtual cut-off	.....	.....	.....	12·76	23·18
Weight in large cylinder at point of release	.....	.....	.....	13·82	23·607
Number of lbs. of water pumped through the condenser per indicated horse-power per hour	333·8	366·4	416·156	406·8	577·04

THERMODYNAMIC EFFICIENCY OF ENGINE CONSIDERED AS PERFECT.

The thermodynamic efficiency of the steam as used in the compound engine on May 10th was computed according to the method given by Rankine (Steam Engine, Art. 284). The pressures of admission and of release and the mean back pressure were obtained from the cards and the corresponding temperatures, densities and latent heats arrived at by using the formulas given in the "Steam Engine" for them (Arts. 206, III, and 255).

The following are the data and results:

p_1 = absolute pressure of admission = 11808 lbs. per square foot.
p_2 = absolute pressure of release = 1363·68 lbs. per square foot.
p_3 = mean absolute back pressure = 704·16 lbs. per square foot.
t_4 = absolute temperature of feed water = 558·36° Fahr.

The corresponding temperatures, densities and latent heats are designated by the same subscripts.

t_1 = 774·50° Fahr. t_2 = 652·32°.
L_1 = 131841·14. L_2 = 19000·39.
D_1 = ·1909. D_2 = ·02606.

From these data the following results were arrived at, by considering the cylinders as non-conducting and the engine perfect. The Rankine formulæ on pages 388 and 389 were employed.

The ratio of expansion $r = 6{\cdot}7167$.
Energy per cubic foot of steam admitted $UD_1 = 27183{\cdot}43$ foot-lbs.
Heat expended per cubic foot of steam admitted $H_1D_1 = 163716{\cdot}507$ foot-lbs.
Mean effective pressure, or energy per cubic foot swept through by piston.

$$\frac{UD_1}{r} = 4047{\cdot}5 \text{ lbs. per square foot.}$$

Heat expended per cubic foot swept through by the piston,

$\frac{H_1D_1}{r} = 24{,}377$ lbs. on square foot = pressure equivalent to heat expended.

$$\text{Efficiency of steam} = \frac{UD_1}{H_1D_1} = \frac{U}{H_1} = {\cdot}166.$$

$$\text{Net feed water per cubic foot swept through by piston} = \frac{D_1}{r} = {\cdot}0284.$$

Cubic feet to be swept through by piston for each indicated horse-power per hour $= \frac{1{,}980{,}000}{M.E.P_1 = 4047{\cdot}5} = 489{\cdot}2$ cubic feet.

Feed water per indicated HP per hour $= 489{\cdot}2 \times {\cdot}0284 = 13{\cdot}89$ lbs.
Actual feed water, $= 17{\cdot}00$ lbs., nearly.

Difference, $3{\cdot}11$ lbs. $= 22$ p. c.

due to cylinder condensation other than that required to perform the work, and other wastes not taken into account in the theory.

CONCLUDING REMARKS.

In these experiments, the data have been obtained and utilized as far as possible with a view to tracing the development and consumption of the energy stored in the coal; and while our results prove the economy to be as great, probably, as that of any previous combination of marine machinery, they also call attention to the great disproportion between the total, and effectively utilized, power, which modern engineering has as yet found little means of reducing.

The results obtained during these experiments show strikingly the relative economy of a somewhat high ratio of expansion and change of type, compared with that ordinarily used upon steamers of this class. The experiments do not in themselves give any marked result as to the relative advantages of simple and compound engines; but as these cylinders were unjacketed, and merely dry steam was used, the objection cannot be urged that compounding has here been united with the improvements and advantages of superheated steam, high pressures, or steam jacketing, and single cylinder engines having about the same ratio of expansion, may furnish valuable examples for comparison.

In the case in hand, however, it would be impracticable to use a ratio of expansion of nearly seven with a single cylinder owing to the great changes of pressure and consequent loss of smoothness in running, as well as other disadvantages of great fluctuations of this sort. The difference of coal consumption is evidently owing in a large degree to the variation of boiler efficiency, the temperature of chimneys in the simple test being much in excess of that in the compound, and consequently the waste of heat greater.

The questions arising, relating to the comparative cost of the two engines, the space they occupy, cost of repairs, etc., all of which enter into the relative commercial efficiency require further data and to some extent can only be settled by experience. These points, however, together with the comparative value of feathering and radial wheels, jet and surface condensers, the most economical point of cut-off, steam jacketing, and other unsettled points in steam engineering upon which these experiments may have a bearing, open a field quite beyond the limits of the present paper.

The authors, in conclusion, would acknowledge their obligations to Mr. Stevenson Taylor, and to the other members of the W. & A. Fletcher Co. for unceasing kindness and attentions throughout the trials, and for securing to them the opportunities for making a thorough test. To Mr. Root, of the Worthington Hydraulic Works, for valued aid and counsel, and to the Fall River Line and its employees for cheerfully rendered voluntary assistance. For aid in the experimental portion of their work, the authors are indebted to Messrs. Barnes, W. Carroll, Maury and Whiting, of the Stevens Institute of Technology, and to Mr. Andrew Fletcher, Jr., of New York.

APPENDIX.

SUMMARY:—The following statement, including other and later figures than those given in the preceding paper, has been prepared, and is kindly supplied by the W. & A. Fletcher Co.

STEAMER "CITY OF FALL RIVER."

Side-wheel Freight Boat of The Old Colony Steam Boat Co., plying between New York, Newport, R. I., and Fall River, Mass. Compound vertical beam engine, H. P., cylinder, $44'' \times 8'$; L. P. cylinder, $68'' \times 12'$. Built by W. & A. Fletcher, North River Iron Works. New York, 1883, and so constructed that the high pressure cylinder can be entirely disconnected, leaving a simple beam engine, cylinder, $68'' \times 12'$.

MEMORANDUM OF RESULTS OF EXPERIMENTS

made to show the relative economy in fuel between a Compound Engine and a Simple Engine.

Trip No.	Date.	Style of engine.	Ports.	Distance statute miles.	Draft of water.	Displacement, gross tons.	Running time.	Average pressure steam per gauge.	Speed per hour.	Revolutions.	Revolutions per minute.
	1883.				ft. in.		h. m.		Stat. miles		
1	May 3....	Compound ...	New York to Fall River.	179	10 7	1948	10 33	68½	16·96	15833	25·01
2	May 4....	Compound ...	Fall River to New York.	179	10 5	1908	11 35	69	15·45	17711	25·5
3	May 9....	Compound ...	New York to Fall River.	179	10 7	1948	11 18	70	15·84	17392	25·65
4	May 10...	Compound ...	Fall River to New York.	179	10 6½	1938	10 46	70	16·62	16060	25·8
5	June 7....	Simple.....	Fall River to New York.	179	10 6	1928	12 04	28	14·83	17286	23·87
6	June 11..	Simple.....	New York to Newport ...	160	10 7	1948	10 26	66	15·34	15287	24·42
7	June 12..	Simple.....	Newport to New York.	160	10 6	1928	10 40	25½	15·	15415	24·1

Trip No.	Date.	Style of engine.	Ports.	Horse-power.	Coal in pounds.	Coal per hour, pounds.	Coal per hour per horse-power.	Water per hour in pounds.	Feed temp'rature of water.	Water per hour per horse-power.	Tide, etc.
	1883.						lbs.			lbs.	
1	May 3....	Compound	New York to Fall River.	1578	.....	.....	.....	26006	104·2	17·	fair.
2	May 4....	Compound	Fall River to New York.	1615	.....	3300	2·04	27718	101·6	17·16	ahead.
3	May 9....	Compound	New York to Fall River.	1611	36800	3257	2·0217	27834	97·	17·3	ahead.
4	May 10...	Compound	Fall River to New York.	1622	35600	3307	2·0388	27854	97·	17·22	fair.
5	June 7....	Simple.....	Fall River to New York.	1347	.....	.....	.....	35271	111·	26·2	ahead.
6	June 11..	Simple.....	New York to Newport ...	1472	43000	4121	2·8	.....	.....	.....	even.
7	June 12..	Simple.....	Newport to New York.	1457	44150	4139	2·84	.....	.....	.....	fair.

GENERAL NOTES.

Fires are well burnt down at end of each trip. When boat arrives at dock, fires are banked and coal put on to keep them alive while steam is blown off. During the day, about noon, more coal is put on fires. An hour previous to departure fires are hauled and spread again with fresh coal, to make steam, and ordinarily no further firing is necessary for half an hour after starting.

On each trip indicator cards were taken every half hour. Water was measured by Worthington's meters, readings taken every hour; meters tested by measuring water, under the same pressure as in pipes when feeding boilers, into a barrel, and weighing four cubic feet at a time; variations of such tests being from 61·4 to 61·5 lbs. per cubic feet. On June 10, the cut-off on Simple engine was shortened, making it easier to keep steam and to run with wide throttle. If meters had not been removed before this the water test would have shown better results per horse-power per hour than was shown on trip No. 5. All Wilkesbarre coal, mined by Lehigh and Wilkesbarre Coal Co. All water measurements, power, calculations and coal measurements of trips Nos. 1, 2, 3, 4, 5 were made by Messrs. Adger and Sague, of the Stevens Institute of Technology, Hoboken, N. J. The power and coal measurements of trips Nos. 6 and 7 were made by W. & A. Fletcher Company.

SPECIAL NOTES.

Trip No. 1, no coal measured. Trip No. 2, coal measured for ten hours run, and of 77½ boxes used 12 were weighed, and average coal per hour found to be 3,300 lbs. Trip No. 3, 6,062 lbs. coal put on fires in New York before starting, to spread fires and make steam. 32,800 lbs. coal put on fires between New York and Fall River. Assuming that it required all of this latter amount, and, in addition, 4,000 lbs. of that put on before starting, makes total consumption of coal 36,800 lbs., as per table. Trip No. 4, 6,711 lbs. coal put on to cover fires and make steam, and 31,609 lbs. on trip. With same assumption as in trip No. 3, makes total consumption 35,609 lbs., as per table. Trip No. 5, no coal weighed. Trip No. 6, 39,000 lbs. coal used on trip. With same assumption as in trip No. 3 and 4, makes total consumption 43,000 lbs., as per table. Trip No. 7, 40,150 lbs. coal used on trip. With same assumption as in trip No. 3 and 4, makes total consumption 44,150 lbs., as per table.

Memorandum of coal as weighed for round trip, May 9 and 10.

	Lbs.
May 9, in New York. To make steam before leaving, 6,062 lbs., on trip to Fall River, 32,800 lbs.	= 38,862
May 10, in Fall River. On banks morn and noon, 2706 lbs., to make steam before leaving, 6,711 lbs.	= 9,417
On trip to New York, 31,609 lbs.; May 11, on banks morn and noon, 2,598 lbs.	= 34,207
Coal used in main boilers	= 82,486
Coal used in donkey boiler and kitchen	= 2,634
Total coal charged to boat	= 85,120
Deduct coal used by engine, as per table	= 72,409
Leaves nearly 3 tons per single trip for banks, spreading, donkey boiler and kitchen	= 12,711

Memorandum of trips, coal and time from F. H. Forbes, G. F. A., O. C. S. B. Co.

Compound Engine, 14 trips, between New York and Fall River, May 15 to June 2. Average time, 11 hours $12\frac{6}{7}$ minutes. Coal 20·65 tons.

Simple Engine, 12 trips, between New York and Fall River, June 4 to 10. Average time, 11 hours $57\frac{6}{7}$ minutes. Coal 27·42 tons.

Deducting 3 tons per trip for banking, spreading fires, donkey boiler and kitchen, all of which is included in the amount of coal given above, makes the actual consumption of coal per trip while engine is running, for Compound Engine 17·65 tons, and for Simple Engine 24·42 tons.

REPORT OF THE BOARD OF EXPERTS ON STREET PAVING.*

The undersigned respectfully submit the following opinion and report on the subject of street pavements in Philadelphia.

The ordinance, approved June 13, 1884, under which you have requested our opinion on this subject defines the purpose of our investigation in the following words, viz:

"SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain*, That for the purpose of obtaining professional advice on the subject of paving the streets of Philadelphia, the Mayor is authorized to obtain from three engineers, distinguished for their knowledge and experience of pavements, a written opinion and report concerning the subject of pavements in Philadelphia, which report and opinion shall be by him transmitted to Councils for their action."

"SECTION 2. The said opinion and report shall be based upon a careful examination of the present condition of the streets of Philadelphia, and shall point out the defects of the present system of paving, and shall specify what, in the opinion of the said engineers, is the best system of pavements for Philadelphia, due regard being paid to durability, economy, smoothness, cleanliness and freedom from noise, and shall further contain an estimate of the cost of such system or systems as they shall recommend."

In order to ascertain "the defects of the present systems" we have made a careful examination of the streets, in connection with data furnished to us by the Chief Commissioner of Highways. We find that the present condition of the streets is as follows:

Paved streets	573 miles.
Macadamized streets	44 "
Unpaved streets	443 "
Total	1,060 miles.

* Report of the Board of Experts on Street Paving to Hon. William B. Smith, Mayor of Philadelphia, July 8, 1884.

On the paved streets the character of pavements is as follows:

Cobble	9,113,925 sq. yds.	93 per cent.
Granite blocks	654,148 "	6⅔ "
Asphalt	25,396 "	¼ "
	9,793,469 sq. yds.	100 per cent.

We find further that the cobble pavements, forming ninety-three per cent. of the total are laid upon a bed of loamy gravel without any sand, that the size of the cobble stones is very irregular, varying from three to fifteen inches in size, and that the system of repairs consists in farming out certain districts to the lowest bidder, who contracts to keep the district in good order during the calendar year for a lump sum.

We find in regard to granite block pavements, sometimes called Belgian, that the blocks are laid upon a bed of gravel similar to that above described, that the joints are not cemented, that different qualities of granite have been used with different results, and that these pavements have been greatly injured by being frequently torn up for underground pipes and are not properly relaid.

We find in regard to asphalt pavements that a certain amount of sheet asphalt has been laid in accordance with what is generally known as the Washington Specifications, and that this pavement looks well, although it has not been laid a sufficient length of time to properly judge of its character; and, also, that asphalt block pavements have been laid in small amounts here and there, some of which look very well, and some, as on Sixth street, near Walnut, very badly.

We also find in regard to the general character of the streets in Philadelphia that they are unusually narrow for a city of its size, the prevailing total width between houses being either fifty or sixty feet, giving only twenty-six and thirty-four respectively for the roadway between curbs; and we also find that these narrow streets are used to an exceptional degree for street railroads, the total length of which amounts to two hundred and three miles, and that where these railroads exist, the carriage-way on each side is reduced to a space of only ten or twelve feet in width, which results in confining the travel in such a manner that vehicles follow each other in lines almost as distinctly marked as the lines of the railroad tracks. These exceptional circumstances have a very important bearing upon the character of pavement to be adopted to meet them.

We find that the macadam is used principly in the suburban sections of the city, such as Germantown, Chestnut Hill, etc., where railroad tracks are not so numerous; although in one instance this class of pavement has been used in the heart of the city (part of Twenty-second street) alongside of railroad tracks. The macadam is usually about ten inches deep, composed principally of a blue gneiss found in the vicinity. Its repairs are farmed out on the same principle as the repairs of the cobble pavements.

Upon the condition of facts above described, we have no hesitation in expressing the following opinions:

First.—That the cobble pavement is the most inferior and the most dangerous to health of all pavements made of stone, and is entirely unfit for use in a large city. It is impossible to maintain its surface in an even condition, because the stones have an uneven bearing, owing to their irregular shape, and its joints are the receptacle for large amounts of street filth, which cannot be removed from them, and which give forth, under the varying conditions of heat and moisture, a variety of vapors and odors which are injurious to health. As it is probable, however, that for financial reasons a certain amount of this class of pavement will have to remain in Philadelphia for some years to come, we are of opinion that its evils can be greatly mitigated by a change in the methods of repairs as follows:

In making repairs the stones should be broken to as nearly as possible a uniform size, and no stones should be relaid whose least dimension is less than four inches or greatest dimension is more than seven inches, and they should be laid with the greatest dimension vertical.

The red gravel on which the stones are now placed, which we find by actual test to contain about sixteen per cent. of clay, should be used as a sub-foundation only, being spread to the depth of six inches, and thoroughly compacted by ramming or rolling. On this should be spread a layer of clean, sharp, river-washed sand, free from clay, dirt, or impurities of any kind, and in size not less than one-thirtieth of an inch. This sand should be at least four inches in thickness, and will make the only proper bed for the stones. After these have been set, clean, washed pebble should be raked over the surface to fill the joints, and the pavement should then be thoroughly rammed with a heavy rammer.

In making these suggestions, we desire to state, that we recommend that no more new cobble-stone pavements be laid under any circum-

stances, but we think that if these suggestions are carried out, the existing cobble-pavements can be kept in better order than at present, until such time as they can be replaced with pavements of proper character; and we think that this can be accomplished at less cost than at present, when in consequence of using poor material, the same street has to be relaid two and even three times in the same year. We also think that the system of farming out the repairs by the year is injudicious, because the contract must necessarily lack that element of distinct specification which is the basis of all good work under contracts.

In our judgment it would be much better to make contracts for repairs, by the square yard of work actually done according to exact specifications, the localities where the work is to be performed, to be pointed out by the proper city official.

Second.—In replacing the cobble-stones, or in laying new pavements, we advise that your choice be restricted to one of the following classes, viz: granite blocks, sheet asphalt, or in exceptional cases, asphalt blocks, the selection among these three being determined by the character of travel, and other conditions which will hereafter be referred to. All of these pavements are perfectly water-proof, which is an indispensable quality of a good pavement.

We are aware that at the present time large amounts of wooden pavements are being laid in London and Paris.

As laid in those cities, upon a foundation of concrete of Portland cement and with blocks of seasoned wood especially treated with preserving compounds—they undoubtedly make a more durable road covering than the wooden pavement which proved so signal a failure in this country several years ago. But according to information received very recently from the French Engineers, it is expected to renew the wood every four or six years, depending on the amount of travel. The first cost of the pavements now being laid in Paris is equivalent to about four dollars per yard, and the contract price for repairs and maintenance is forty-nine cents per yard per annum, the contract being made for eighteen years. This brings the total cost during eighteen years to twelve dollars and eighty-two cents, which is about three times the cost, during the same period, of the pavement which we recommend. On account of its cost, both for construction and maintenance, we do not recommend the wooden pavement for the City of Philadelphia.

We advise that the granite block pavement be used exclusively on all streets where the distance between rail and curb (or, if there be no railroad, between curb and curb) is less than twenty feet, also on all streets in the business section of the city where the travel is unusually heavy—say more than fifty trucks or other heavy wagons per hour, and on all streets without regard to width or traffic where the grade is steeper than three in one hundred, except those streets where asphalt blocks are admissible, as hereinafter specified.

We advise that sheet asphalt be laid in spaces near public buildings where quiet is particularly desireable, provided the space is sufficiently wide (more than twenty feet) and the grade not too steep (less than three-one-hundredths) also on streets which are occupied exclusively by dwelling houses and where there are no railroads. As instances of snch localities we would cite the space around the new Public Buildings, and on Broad street, the north end of Broad street, Twenty-first street south of Market, portions of Locust street in the vicinity of Rittenhouse square, Diamond street, and other streets of the same character on which there are no railroads. In laying asphalt along railroad tracks, in broad spaces like that surrounding the new City Buildings, a space not less than one foot in width next to the track should be paved with granite blocks, the ends of the blocks toothing into the asphalt.

The asphalt block pavement is somewhat inferior in wearing qualities to the sheet asphalt, but it has great advantages in being cheaper, and in requiring no special plant or skilled labor to lay it. It is well adapted, provided the blocks are properly made, to streets of light travel, occupied solely by residences; but it is proper to state that there is great difference in the quality of these blocks, as ordinarily made, and corresponding risk in adopting them. For heavy traffic they have usually proved a failure. This pavement would be suitable for many of the residence streets of West Philadelphia, but it should not be used on streets where there are railroad tracks, or where the grade is steeper than four-one-hundredths. For the suburban streets of Germantown, Chestnut Hill and similar sections, we recommend that macadam continue to be used, at least until the travel on them becomes very much greater than it is at present.

Having thus indicated the general character of the pavements and the conditions which govern the selection and use of each, we will now speak more in detail of the manner in which they should be constructed and laid.

THE GRANITE BLOCK PAVEMENTS

Should be laid on a foundation of concrete six inches in thickness; or upon a bed of strong clean gravel of the same thickness, formed to the cross-section of the street, and thoroughly compressed by rolling with a steam roller such as is hereafter described, and all subsidence made good by additional material. In case the blocks should be bedded in three inches of sharp washed sand, free from clay or other impurities; the joints should be filled with a preparation of clean, dry pebbles, (heated if laid in damp weather) and the coal tar product known to the trade as No. 5.

In regard to the foundation, we are of opinion that for ordinary traffic the concrete is unnecessary, provided the work is properly done. Well compacted dry earth is an excellent foundation, provided it is kept dry; and if the joints are properly filled with tar and gravel the pavement becomes absolutely water-proof, and no settlement can occur. If, however, the work is not properly executed and the joints not properly filled then water will penetrate to the foundation, and settlement and inequalities will occur. There can be no doubt that the concrete foundation provides against all contingencies. Its use increases the cost of the pavement by about eighty cents per square yard. On streets of the heaviest travel it would doubtless be best to incur this extra expense, although, as previously stated, we do not consider it necessary where such an earth foundation as we have described is kept perfectly dry, and the traffic is not very heavy.

In regard to the quality and size of the blocks, we recommend the Quincy granite as a standard, and all blocks should be equal to this in toughness and hardness, should be of uniform texture, and free from weathering.

Hard, basaltic stone, that will take a polish under travel, should be rejected, as should also the softer quality of granite, and all other gneiss and other laminated stones. The blocks should not be less than three or more than four and a half inches in thickness, six, seven, or eight inches thick, according to the amount of travel, and in length about one and a quarter times their depth. A pavement with narrow blocks affords a firmer footing to the horse, and is less noisy than one with wider blocks; but the thickness cannot be reduced below three inches without impairing the strength of the block. Variations in

length may be permitted to the extent of two or even three inches, but in depth the blocks should be as nearly as possible uniform; no variation greater than one-half inch being permitted. It is impossible to lay a good pavement with blocks of unequal depths, for under travel the blocks will find a level bearing underneath, and all the inequalities will be on the surface. The blocks should be carefully sorted as to width, and those of the same width be used in the same portion of the street. Each block should be regular in shape, with rectangular edges and smooth faces, having no projections nor depressions greater than one-half inch. We advise that the blocks be laid invariably with tar-cemented joints, so as to make the pavement water-proof. No open-jointed pavement should be laid in a city, on account of the large spaces between the blocks giving access into the soil below for the urine and other foul waters of the street, and giving out fumes not only to the street in summer time, but, through heating and ventilating systems, to the interior of houses in winter. With blocks six inches deep and regular in shape, so that the joints will not be too wide, about three and a half gallons of tar will be required to the square yard, and the cost of this is about twenty-five cents. The advantages of the water-proof joints are fully worth this price.

We recommend that the city purchase the blocks which it may intend to lay several weeks or months in advance, so that they may be carefully inspected on delivery, and all blocks which do not conform to the specifications can be rejected. Separate contracts can then be made for laying the blocks after they have been inspected. We estimate the cost of granite block pavements, laid with tar joints in the manner we have described, as follows, per square yard.

	6 in. deep.	7 in. deep.	8 in. deep.
Cost of blocks	$1 80	$2 00	$2 25
Cost of laying	80	85	90
Total	$2 60	$2 85	$3 15

From these prices not less than fifteen cents should be deducted, if the old cobble now on the streets is to be given to the contractors, and 80 cents should be added to them if a concrete foundation is used.

ASPHALT PAVEMENTS.

Under the name of asphalt, a large variety of mixtures have been laid as pavements, but all those which had any value at all belonged to one of three classes, viz:

1st. The largely asphalte comprime, which is largely used in Paris and other European cities. This is made from an amorphous limestone, naturally and intimately impregnated with bitumen, found in the Vosges Mountains, and in Sicily and Hanover. It is reduced to powder, heated, placed on a concrete foundation, and then thoroughly compressed by ramming and rolling.

2d. The American asphalt mastic, which is the standard pavement at Washington. This is an artificial compound, made of refined Trinidad bitumen, powdered stones, and sharp sand. The mastic is placed on a concrete foundation when hot and plastic, and thoroughly compressed by rolling.

3d. The coal-tar concretes, improperly called asphalt, in which the foundation was of broken stone and coal-tar, and the top surface of sand, or fine pebbles, and coal-tar, made into a mastic, spread and rolled substantially as above.

All three of these classes of pavements, when manufactured with skilled labor and laid with proper care, have resulted in good roadway.

The coal-tar pavement is not recommended by us, for the reason that the cementing substance is a product of gas-tar, obtained by interrupting the destructive distillation of that compound, after it has reached a certain point. When placed on the street and subjected to atmospheric influences, a slow and gradual oxidation takes place, by which the tar loses its cementing qualities and becomes inert. The particles of sand then lose their cohesion, and the pavement rapidly disintegrates.

The price of the asphalt comprime in this country at present would not be less than three dollars and fifty cents per square yard. The American asphalt mastic can be laid at a profit for two dollars and twenty-five cents. The asphalt comprime is at times very slippery—an objection to which the American pavement is less subject. There has not yet been sufficient experience as to the comparative cost of repairs of these two classes of pavement to state definitely which is the more durable. Therefore we recommend, at least until further experience, that the American asphalt be used in Philadelphia, in such localities as we have indicated.

A foundation of concrete of the best American hydraulic cement, six inches in thickness, is indispensable for any asphalt pavement. It

is, in fact, the pavement itself, the asphalt surface being merely a cushion to break the force of the travel.

The proper preparation and laying of both the asphalt comprime and mastics is so largely a matter of expert manipulation, besides the necessity for purity in the material, that rigorous specifications are liable to be used by an incompetent or dishonest contractor as an excuse for bad work. In order to obviate their difficulty, it has been the practice for several years in London and other European cities to let contracts for this class of pavement only on satisfactory bond or deposit for maintenance during a period of not less than fifteen years at a specified rate per square yard per annum, the amount of subsidence or dilapidation calling for repairs being rigorously specified, so that it can be clearly understood by the residents on the street as well as the parties to the contract. This system, although it has never been introduced into this country, has met with such uniform success abroad that we recommend it as worthy of the most careful consideration and a full trial.

We recommend that no proposition be entertained looking to the covering of the cobble stones with asphalt or any other compound. Such work will result in nothing but failure, and will create a nuisance on the streets. The reason of this is that the asphalt compound, having no transverse strength of its own, requires an absolutely rigid and unyielding foundation. Cobble stones do not fulfil this condition.

ASPHALT BLOCKS.

These blocks are made of Trinidad asphalt and small particles of lime-stone, mixed together in certain proportions and pressed in a mould under heavy pressure. They are ready for laying as soon as received from the factory. The size of block usually manufactured is twelve inches long, four inches wide, and five inches deep, and we see no reason to change these dimensions. In regard to its foundation, the same remarks apply as already made in regard to granite blocks, *i.e.*, if the foundation is well compacted and perfectly dry, a concrete bed is unnecessary; but the concrete prevents the chance of poor work. The blocks are of such uniform size that the joints are extremely narrow, and the asphalt on the sides soon unites so as to make the pavement water-proof. Asphalt block pavements can be laid at a profit for two dollars and ten cents per square yard on a foundation of gravel and

sand. From this should be made the same deduction for old cobble, and the same addition for concrete foundation, as previously noted.

MACADAM.

In laying new macadam roads in the suburban districts, we recommend that, if the ground be at all springy or damp, a bed of sand or of blast furnace slag, six inches in thickness, be laid as a foundation, and thoroughly rolled.

This will provide most effectually for the drainage in the wet season. The macadam proper should be ten inches in thickness, spread in two layers, each of sufficient thickness to be five inches thick when thoroughly compressed. This compression should be obtained by a steam roller weighing not less than ten tons, and employed for not less than ten hours on each one thousand square yards of each layer. As the use of heavier rollers than can be drawn by horses is necessary for the best type of macadam roads, and as the expense of purchasing a steam road-roller will deter contractors, without assurance of more than one season's work, from bidding on macadam where such purpose is necessary, we recommend the purchase by the city of three rollers, weighing not less than ten gross tons each and not less than two tons per foot run. We estimate the cost of such rollers at about five thousand dollars each. These rollers can be used for compacting foundations for pavements, as mentioned above, as well as for macadam roads, being rented to contractors under proper regulations. In the spring, when the roads are soft, it will be found advantageous to go over all of them, rolling down any projecting stones and bringing the surface to proper shape with fresh materials where any depressions occur, without waiting for the road to be worn out. This, on roads of light travel, with cleaning and watering, will probably be sufficient until fall; on roads of constant and heavy traffic, a roller and store of broken stone should at all times be at the disposal of the engineer in charge, so that the surface can be kept perfect.

For new roads, the bottom layer, which may be of gneiss or limestone, broken to pass through a four-inch ring in their largest dimension, should be placed on a thoroughly compacted bed, as before specified. In rolling this course as above specified, a watering cart and trap screenings should be on hand for use in case the stones begin to roll on each other. When thoroughly compacted, the top course, which should be of tough trap-rock, broken to pass over a one and a quarter inch

hole and to pass through a two and a half inch hole, and free from flat pieces or spaulls, should be rolled with the same precaution as two water carts and screenings, as above, till thoroughly compacted. When fine, dry screenings should be slowly spread, and rolled in until all interstices are thoroughly filled and a coating of powdered screenings one-quarter inch thick remains on top of the stone, when the road should have a plentiful supply of water from a sprinkler directly in front of the roller, which should be kept in motion till all the surface behind it is puddled or has a mottled appearance, when a light coat of screenings will finish the road, and after a few hours drying it can be thrown open to traffic.

The intention of this is to, first, afford a cheap foundation, and, secondly, to make a hard, compact, and, as nearly as possible, homogeneous wearing surface. For this reason trap screenings were specified in the lower coat, as softer screenings, if allowed on the ground, will be worked into the top coat. Any soft material used as "binding" will reduce the cost and labor of rolling, but will make a softer, dirtier, and more perishable road. On country roads a superior economy, resulting from the use of clay or other soft material, may justify it, but on suburban roads all soft material should be rigorously excluded.

A macadam road should be maintained by thoroughly wetting any depression and rolling in stones from one to one and a half inches in size, in order that general repairs, except on heavily traveled roads, should seldom be necessary. The dust and debris of a macadam road should not be swept off in dry weather, unless water enough can be afforded to make a very liquid mud. When that is attained, naturally or artificially, a soft revolving broom should be used, with such draft that the heavy debris is not removed. When there is an inconvenient amount of trash on the road, the same broom, with a lighter draft, can be used to remove it. The road should not be scraped, and should be let alone when the mud is not sufficiently fluid.

We estimate the cost of a macadam pavement, laid in the manner we have described, at one dollar and seventy-five cents per square yard.

In conclusion, we submit the following recommendations of a general character:

All contracts for pavements (excluding macadam) should contain a clause by which the contractor guarantees to keep the pavement in good repair for a period of not less than five years from the date of its acceptance by the city, and to insure a compliance with this guarantee,

the city should retain ten per centum of its cost until the expiration of the five years term.

No pavement, no matter how well laid, can be kept in proper order if it is constantly disturbed for the purpose of laying or repairing underground pipes. In order to avoid this as far as possible, all drains, gas, water, and other pipes, should be laid, or if already laid should be thoroughly repaired, before the pavement is put down. Such openings in the street as subsequently become unavoidable, should be made only by permission of the city officials in charge of the streets, and under their direct supervision; and before such permits are granted, the applicant should be required to pay the estimated cost of repairing and relaying the pavement, and these repairs should be made under the immediate direction of the same official, who should be held responsible that they are made properly.

The crown or transverse section of the pavement should be the arc of a circle, with versine about one-eightieth of the chord, or say for

Streets 26 feet wide, crown 4 inches.
Streets 34 feet wide, crown 5 inches.
Streets 50 feet wide, crown 7 inches.
Streets 70 feet wide, crown 10 inches.

In wider streets these may be slightly reduced when the longitudinal slope exceeds three one-hundredths. The distance from top of curb to surface of pavement at the curb should be between five and seven inches, depending on the width of the street.

In cases like that of Locust street, between Sixteenth and Seventeenth streets, where the ground is soft and full of springs, we would advise that "blind" or broken stone drains be laid under the foundation, these drains being connected at their lower ends with drain pipes leading into the nearest sewer or inlet. A concrete foundation should be laid on all such streets as a further protection against settlement. No sewer pipe intended to carry house drainage should be laid with open joints for the purpose of draining the soil. Such pipes would speedily pollute the soil and produce sickness.

The ordinance under which we have made this report requires that the report shall "contain an estimate of the cost of such system or systems as we shall recommend." We have already stated that the cost per square yard of the standard pavements which we recommend, is as follows:

7 inch granite blocks on concrete feundation,	$3 65
6 inch granite blocks on gravel foundation,	2 60
Sheet asphalt on concrete foundation,	2 25
Alphalt block on concrete foundation,	2 90
Asphalt block on gravel foundation,	2 10

Although the existing granite block pavements are not cemented in the joints, yet they are so much better than the cobble pavements, that it is not likely that any plans for relaying them will be considered at present. This leaves the 535 miles of cobble pavements, containing in round numbers 9,000,000 square yards. Of this a length of 203 miles is traversed by street railroads, between the rails of which we would advise that the cobble be allowed to remain for the present. This reduces the area by about 600,000 yards, leaving 8,400,000 yards to be repaved. It is not probable that more than 80 miles of streets, say 1,400,000 yards—will fulfill the conditions which we have named as limiting the use of asphalt pavements, and of this not more than one-fourth to one-third should be asphalt block.

We have then seven million yards remaining for granite blocks, and of this perhaps one million yards in the heavy business streets, should be deep blocks laid on concrete.

This gives the data for the following approximate estimate, viz.:

1,000,000 square yards granite block a.,	$3 65	$3,650,000
6,000,000 square yards granite block a.,	2 60	15,600,000
1,100,000 square yards sheet asphalt,	2 25	2,475,000
300,000 square yards asphalt block,	2 10	630,000
8,400,000 square yards,		$22,355,000

From this should be deducted the value of eight million four hundred thousand yards of cobble, at fifteen cents, one million two hundred and sixty thousand dollars, leaving the net cost twenty-one million and ninety-five thousand dollars.

It is estimated that two million dollars could be advantageously expended in each year, in laying about fifty miles of improved pavements so that the cobble stone would be entirely replaced in between ten and eleven years.

These estimates are necessarily general and approximate only. They are given merely for the purpose of stating what will be the probable ultimate cost of replacing the cobble stones. Our estimate of prices per square yard is based upon the actual cost of similar work in

other cities during the past few years, and it may be relied upon as reasonably exact, at the present prices of labor and materials.

Respectfully submitted,

(Signed) Q. A. GILLMORE,
F. V. GREEN.

The undersigned agreeing with the above, wishes to add a recommendation that in the case of all pavements except those laid on concrete when the ground is wet or soft, a layer of fine sand or blast furnace slag be placed or rolled under the bed of gravel specified, with the purpose of preventing the subsidence of the gravel into the clay.

Also, for the lanes or alleys in the old part of the city, where water is discharged into the gutters, the use of rock-asphalt mastic made from either one of the following brands, viz.: *Val De Travers or Neuchatel, Seyssl*, or the mastics of the *United Limmer Company*. These mastics when properly laid are not disintegrated by hot or other water, and can be laid so hard that wheels following in one track will not injure them. This pavement can be laid on six inches of concrete, one and one half inches thick, for two dollars and seventy-five cents per square yard, and the gutters will be so smooth that water will not lodge in them as at present.

Very respectfully,

(Signed) EDWARD P. NORTH.

INFLUENCE OF MAGNETIC PERTURBATIONS UPON SCINTILLATION.—Montigny has published a series of observations, from which he draws the following conclusions: 1. The intensity of scintillation upon the day of a magnetic storm is greater than that upon the preceding or upon the following day, provided those days are free from magnetic disturbance. 2. The increase of scintillation is very marked when the disturbance comes on or persists at the very moment of observation. 3. The path described by the image of the star in the telescope is generally less regular on the days of disturbance than on the previous or on the following day, provided the atmospheric conditions are the same. 4. The increase of twinkling during periods of drought and of magnetic storms is equivalent to the excess of the increments of twinkling, under the influence of magnetic disturbances which arise during rainy periods. In connection with his observations, Montigny refers to the experiments of Henri Becquerel and M. Jubert, upon the influence of terrestrial magnetism on the plane of polarization of a ray of light traversing a tube filled with bi-sulphide of carbon and placed in the magnetic meridian.—*Bul. de l'Acad. de Belg.*, 1883. C.

SURVEYS FOR THE FUTURE WATER SUPPLY OF PHILADELPHIA.

By RUDOLPH HERING, C. E., *Assistant in Charge.*

(Continued from page 152.)

The lines for the proposed conduit to the Perkiomen were run as follows:

Starting at the site of the proposed Cambria reservoir, the line follows the best course to the Wissahickon creek, which it crosses near the old log cabin. Following the west bank for about five miles, with several short tunnels, it reaches a point about one mile north of Barren Hill, where two alternate lines diverge. One continues up the Wissahickon valley; the other runs towards Norristown.

The latter, through a short tunnel, reaches the Plymouth creek, crosses the Plymouth Railroad overhead, continues through Cold Point and the northern part of Hickorytown to a point about two miles northeast of Mageetown, where a short tunnel brings it into a small valley; then, with another tunnel, it reaches Saw Mill Run, at the northeast corner of the borough of Norristown. From Hickorytown an alternate line to this point shortens the distance, but increases the length of tunneling. The line then crosses the Norristown ridge with a tunnel into Stony Brook valley, crosses the railroad overhead, and then runs to a point one and a half miles southwest of Norritonville, whence a tunnel, about three miles in length, carries it into the Skippack valley. The width of this valley at the most favorable point for crossing is about two thousand one hundred feet. Passing Skippackville, the line reaches a point near Amityville, whence two tunnels bring it into the valley of the Northeast Branch of the Perkiomen, about one mile southwest of Lederachville. Crossing this stream, and following its western bank to near Branchville, it passes through another tunnel, and reaches Sumneytown and the proposed storage dam. From a point about one mile north of Lederachville, an alternate line was run directly to the Perkiomen at Salford Station, requiring a shorter tunnel.

The alternate line, diverging near Barren Hill, follows the west side of the Wissahickon to a point near Gwynedd Station, thence to Towamencin Creek with a five mile tunnel, which, if a higher grade is adopted, can be reduced to two and a half miles, and finally joins

the line before mentioned, near Lederachville, after crossing the Skippack two miles northeast of Skippackville, and passing through another tunnel.

Topography was extended sufficiently far to examine still other alternate lines. Only one line remains to be run from a suitable point on the present line to opposite Schwenksville, and thus complete all practicable locations for a conduit into the Perkiomen basin on the proposed grade.

A careful survey was made of the entire country to be flooded by the proposed dams at Schwenksville, Green Lane, and Sumneytown, and the general topography of the water-shed of all the ground west of the Perkiomen and of the Macoby was taken, up to the county lines where it joins the territory covered by the State Geological Survey.

Mr. Linton was assisted in this work by
George B. Mifflin, transitman, appointed June 12, 1883.
Kenneth Allen, leveller, appointed May 30, 1883.
R. T. Vaughan rodman, appointed May 80, 1883, left December 22d.
H. A. Schofield, rodman, appointed May 28, 1883.
Amasa Ely, chainman, appointed May 28, 1883, left September 6th.
W. E. Parker, chainman, appointed September 10th.
Max Atlee, flagman, appointed May 28, 1883, left December 22d.
George W. Wood, axeman, appointed June 4, 1883, left December 22d.

(*b.*) *Lehigh Party,* Mr. A. P. Berlin, C. E., in charge.

The object in view in making an examination of the Lehigh water-shed was simply to collect enough information to have a reasonably fair knowledge of its value in connection with the Perkiomen scheme, and to ascertain the feasibility of a conduit discharging into the Perkiomen basin. No detailed surveys were contemplated or made.

Mr. Berlin, of Easton, Pa., being familiar with the country, was entrusted with the duty: First, of collecting all existing maps and information that would assist in the work; and Secondly, of making a reconnaissance of the entire water-shed, noting its general physical and topographical features, in order both to correct and to supplement existing maps.

He began his work July 19th, and completed it September 4th. He was assisted from July 23d to August 17th by Mr. C. P. Bassett.

The maps that were procured and copied are as follows:

1st. Lehigh Valley Railroad from the Summit above White Haven to Allentown, with 20 feet contours extending some distance from the line.

2d. Warrantee Tract Map between the Lehigh Valley and the D. L. & W. R. R., and between the Lehigh and Susquehanna Rivers.

3d. Profile and general topographical features of Bear Creek Valley.

4th. The township maps of the counties situated in the water-shed under consideration.

Mr. C. E. Stedman, Chief Engineer L. V. R. R., rendered valuable assistance in securing and loaning existing maps, etc.

The field work consisted in reconnoitering the territory which drains into the Lehigh at White Haven and in recording about 500 aneroid elevations. But few sights and angles were taken, as it was not deemed necessary for the present inquiry to spend the time for an accurate survey. The Luzerne county map was found to be quite reliable; the Monroe county map fair; and the Carbon county map very inaccurate. Contours were sketched every twenty feet over the water-shed in the following townships: Tobyhanna, Coolbaugh and Tunkhannock, in Monroe county; Buck and Bear Creek, in Luzerne county; Dennison and Covington, and a portion of Kidder and Penn Forest, in Carbon county. The elevations were reduced to sea level.

The topography as thus obtained gives a fair idea of the territory for the purposes of ascertaining the area of the water-shed, as well as its general features for collecting and storing water.

The area which may be utilized for the water supply of the city is almost entirely covered with forests in different stages of growth. The streams furnish a very uniform flow, comparatively, and the water is excellent throughout. The main tributary to the Lehigh is the Tobyhanna river in Coolbaugh township, draining several lakes and ponds. The Tunkhannock and Trout creeks are small but steady streams which discharge into the Lehigh on the south side: the Bear, Wright's Shades, Cloke, Cold Spring, and Pond creeks empty into it from the north. The entire water shed is from 1,100 feet to about 2,000 feet above the sea, too high ever to be much used for agriculture. The soil, furthermore, is everywhere coarse and stony.

A conduit bringing the water down the valley would be situate on the left bank, at least as far down as below Mauch Chunk, and intercept all the streams crossed. It would then follow down through the Lehigh Gap, continue near the river to Siegfried's Bridge and then

leaving it, cross the country towards the Perkiomen. A tunnel of less than four miles would permit the Lehigh water to discharge into the Perkiomen basin near Hossensack, at an elevation of about 400 feet above city datum.

The great fall available for the conduit would permit its diameter to be smaller, and thus its cost may compare favorably with that of other schemes requiring less length of conduit.

(c.) *Delaware Party*, F. L. Paddock, C. E., in charge.

The field work commenced June 6, with a small party, but from June 12 was continued with a full corps until December 17, or for 167 working days, when office work was begun.

During this time 305·68 miles were measured with steel tape, of which 113·42 miles were for conduit lines; 317·1 miles were measured by stadia and gradienter; 1,558 vernier angles were turned; 6,743 magnetic bearings were taken with the transit; 183·7 miles were leveled with the "Y" level and 272 bench marks were established.

The areas covered by the surveys were

23	square miles for conduit lines,
1·5	square miles for storage basins, and
20	square miles for general water-shed.
44·5	square miles.

Four and two-thirds months were devoted to the survey of a conduit line to the Delaware Water Gap, which was run as follows:

Two alternate lines were located from the city to Huntingdon Valley, beginning at the city line near Second street, west of Tacony Creek. One runs to Fox Chase, and thence to the junction of Harper's Run with the Pennypack creek and along the west bank of the latter to Huntingdon Valley. The other, longer in distance but requiring less expensive work, extends in a northwest direction to the left of Ashbourne on the North Penn R. R., strikes the Tacony creek near Shoemakertown, and thence follows the west bank of this creek to its head near Jenkintown. From here it follows down Paul's Brook to the Pennypack creek, where it joins the other line near Huntingdon station.

The conduit line then extends up the Pennypack, on its west bank, to the Forks, whence again several alternate lines were run: one through Johnsville to the west of Jacksonville, striking the Little

Neshaminy at Rosse's Mill; another follows up the Eastern Fork of the Pennypack to Danville, thence to Nippe's Run, back of Jacksonville, and down the latter to the Neshaminy; and a third passes Hartsville station near the head of the Warminster Creek, and follows the same to its junction with the Little Neshaminy. The country over which these lines run is the dividing ridge between the Pennypack and Neshaminy waters and will require a tunnel about two miles in length.

From Rosse's Mill the line follows the west bank of the Little Neshaminy, and crosses the Big Neshaminy west of the Forks. Thence it extends up Mill Creek to Lahaska Creek, and follows the latter to Greenville. Here another dividing ridge requires a tunnel 2½ miles in length, which brings the conduit line to Carversville.

An alternate line was run in a northeasterly direction from near Vandegroft's Mill to the Trout Ponds or Ingham Springs, near New Hope, passing up one of the branches of Pidcock Creek to Clayton, and through a gap between the Solebury and Buckingham Mountains, down to the Springs.

Another line was run from the head waters of Pidcock Creek, to Glendale, whence it was intended to extend it by a short tunnel through the Solebury Mountain, to Aquelong Creek, and thence to New Hope.

From Carversville the first line follows the valley of the Paunaucussing Creek down to the Delaware river at Lumberville, and continues on or near its western bank up to the Water Gap.

About one and a third miles above Lumberville, and at the mouth of the Tohickon Creek, it reaches Point Pleasant, where the conduit might temporarily terminate. The distance from the Frankford Reservoir to this point is thirty miles.

Contrary to expectations gained from previous reports, the above line as far as Point Pleasant is found to compare well with the lines to the Perkiomen. The length of tunneling is much less than was supposed, and there are but but few valleys to cross. No detailed comparison has as yet been possible, except to observe that their length and the amount of tunneling necessary are about the same.

After crossing the Tohickon Valley the conduit would follow the bank as far as Tinicum Creek. From there it can run either in a direct line to a point west of Kintnersville, about a mile from the river, cutting off an extensive bend in the same by a five-mile tunnel, pro-

bably mostly through trap rock, or it can follow the river along a very steep bluff through sandstone and slates. Above Kintnersville the conduit runs inland as far as Monroe. At Easton it crosses the Lehigh river, follows along Second street, and then crosses the Bushkill Creek, all by means of one inverted syphon 3,900 feet in length. From here to the Gap the line is not troublesome.

The party devoted the remainder of the season to running a tie line from Point Pleasant, on the Delaware, to Schwenksville, on the Perkiomen, to connect the levels and lines of the two parties, also to surveying sites for storage basins in the Tohickon Valley, and to crossing the same with a few base lines from which to take the topography during the following season.

Mr. Paddock was assited in this work by
W. T. Forsythe, transitman, appointed June 10th.
E. C. Bull, leveler, appointed June 5th, left December 20th.
Jacob Stadleman, rodman, appointed June 4th, left July 7th.
Isaac Forsythe, rodman, appointed June 4th, left December 20th.
G. S. Cheyney, chainman, appointed June 4th.
Ross Kirk, chainman, appointed July 9th, left November 3d.
C. E. Taylor, axeman, appointed June 18th.
Thomas Jamison, flagman, appointed June 5th, left December 20th.

B. HYDROGRAPHIC WORK.

The hydrographic branch of the investigation was intrusted to Mr. C. S. Gowen, C. E. He reported for duty June 24th, and has since been engaged in ascertaining.

1. The flow of the different streams in the Perkiomen, the Neshaminy and Tohickon valleys;

2. The minimum flow of the Delaware and Lehigh rivers; and

3. The rainfall on the Delaware, Schuylkill, and Lehigh basins in general, and on the Perkiomen, Neshaminy and Tohickon basins in particular.

For the Perkiomen project it was decided to gauge the following streams:

The Perkiomen at Green Lane and Schwenksville.
The East Swamp Creek at Sumneytown.
The Macoby at Green Lane.
The West Swamp Creek at Zieglersville.
The Northeast Branch, one and a half miles above Schwenksville.
The Skippack at Skippackville.

For the Delaware project it was decided to gauge the Pennypack at Shelmire's mills, the Neshaminy at the Forks, and the Tohickon at Point Pleasant.

A careful search was made for proper sites at which to place the gauge posts, and where to build the necessary weirs and to place current meters, so that reliable results could be secured at the least expense.

It has not yet been possible to compute the results of this season's work. It may, however, be stated in general, that the combined minimum, and also the mean flow in the Tohickon and Neshaminy Creeks from July to December 1st was considerably less than in the Perkiomen and its branches, but that in December their combined mean flow was somewhat larger.

This results is no doubt due partially to the fact that the rainfall on on the Perkiomen water-shed was somewhat greater, and also to the fact that the territory about the headwaters of the Perkiomen is more wooded, and therefore prevents evaporation and immediate discharge better than the territory near the head of the Tohickon and Neshaminy water-sheds, which is mostly cultivated land.

From the fact that the many mill privileges cause a very irregular flow by the storing of water and its subsequent rapid discharge, it is extremely difficult to get accurate results. Automatic gauges would obviate this difficulty, and it may be advisable, after the last year's work is compiled, to establish several in both the Perkiomen and Delaware divisions during the following season.

Appended will be found drawings of two types of weirs, as built, one being in soft ground, as on the Perkiomen above Green Lane, and the other on rock, as at the Forks of the Neshaminy.

To ascertain the minimum flow of the Delaware and Lehigh rivers, suitable localities were selected, and meter measurements were taken at the lowest stages of the rivers. It was stated at the time when our measurements were taken, that the river at the Water Gap had not been as low for many years. The minimum flow of the Delaware at that point was found to be 697 million gallons per day, and of the Lehigh, at White Haven, 76 million gallons per day.

The flow of the Schuylkill river has heretofore been approximately measured by ascertaining the quantity of water pumped, the quantity used for the wheels and for the locks, and estimating the leakage, when no water was flowing over the dam. It was, therefore, not deemed necessary at this time to make any further measurements.

The rainfall question next received consideration. Gauges, such as

are used by the United States Government, were placed at every point where it was desirable to measure the precipitation and where no observations had previously been made. In order to ascertain the intensity of the storms, especially during the heaviest fall, and to leave an exact record of their duration, automatic gauges were required. After considerable search for the best instruments, we succeeded in having three made according to the pattern of Prof. Draper, in charge of the Meteorological Station at Central Park, New York City.

The rainfall records of numerous volunteer observers, stationed on or near the water-sheds under consideration, have been collected and are appended. These, together with our own, will, when compared, enable us to determine the amount of precipitation on the Perkiomen, Neshaminy and Tohickon water-sheds. As yet no complete comparison of the results has been possible. The only conclusion which can be given so far is that the rain-fall on the Perkiomen water-shed during the last six months of 1883, was somewhat greater than that on the Tohickon and Neshaminy water-sheds.

The nature of the work of the hydrographic party being such that even one whole season's results cannot lead to a final conclusion, owing to the varying intensity of the seasons during the different years, it is essential that the observations should be continued for several years without interruption. To cease gauging the streams continuously before the final adoption of one of the projects, might result in serious consequences. The absence of a full record might easily, for instance, cause the assumption of an erroneous quantity for the necessary storage capacity on the different streams.

The expense of permanently continuing this work, now that the weirs are built and the guages set, would not be considerable, and certainly would be worth much more than its cost. In connection therewith the rain gauging should likewise be continued, at least for several years. New York and Boston both continue permanently rain and stream gauging connected with their water supplies.

Mr. Gowen was assisted in his work by

H. W. Sanborn,	sub-assistant,	appointed	July 20.
E. S. Crawley,	rodman,	"	June 25, left Sept. 8.
Amasa Ely,	"	"	Sept. 7.
H. C. Shurtleff,	"	"	Oct. 2, left Dec. 11.
B. Franklin,	"	"	July 17, " Aug. 17.
E. S. Campbell,	"	"	Aug. 20, " Sept. 8.
G. A. Luccareni,	"	"	Sept. 6, " Oct. 31.
J. G. Hillsman,	"	"	June 30, " Dec. 15.

PRECIPITATION—IN INCHES AND HUNDREDTHS—1883.

STATION.	Elevation above sea level.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total for year.	OBSERVER.
Phila. Water Dept. (automatic)	110	.....	.....	.....	.....	.....	.....	.....	.....	.....	3·37	1·22	2·71	.....	Phila. Water Dept.
U. S. Signal Service, Phila.	140	4·13	5·04	2·02	2·44	1·91	5·91	1·78	3·40	4·26	4·18	1·34	2·76	39·17	T. F. Townsend.
Pennsylvania Hospital, Phila.	50	3·78	4·79	2·43	2·98	1·95	5·96	2·04	4·11	4·43	4·11	1·56	3·15	41·29	Penna. Hospital.
Moorestown, N. J.	48	4·05	4·77	2·33	3·08	4·70	4·51	1·57	4·07	4·77	5·22	1·48	3·25	43·81	Thos. J. Beans.
Fallsington, Penna.	44	4·07	4·60	2·60	3·88	3·34	5·04	2·05	5·36	3·64	4·02	1·56	3·31	43·47	Millnor Gillingham.
Princeton, N. J.	216	3·72	4·40	1·65	2·46	2·40	6·32	1·57	3·60	3·26	3·34	1·48	2·75	36·96	M. McNeill.
Doylestown, Penna.	387	.....	.....	.....	.....	.....	.....	.....	.....	.....	3·80	1·43	3·06	.....	Phila. Water Dept.
Doylestown, Penna. (automatic)	387	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1·39	2·21	.....	Phila. Water Dept.
Ottsville, Penna.	340	.....	.....	.....	.....	.....	.....	.....	.....	.....	4·71	1·82	4·05	.....	Phila. Water Dept.
Quakertown, Penna.	536	3·40	3·20	1·69	2·65	2·09	6·98	1·05	2·25	3·72	4·10	1·47	2·15	34·75	J. H. Heacock.
Phillipsburg, N. J.	163	.....	3·06	.....	1·71	1·86	4·97	4·92	1·44	3·99	4·81	.....	.....	.....	Emily Kent.
Easton, Penna.	328	3·20	3·87	2·40	2·94	2·68	4·62	4·86	2·36	4·27	5·22	1·61	3·36	41·39	Prof. S. J. Coffin.
Mouth of the Perkiomen, Penna.	87	3·83	4·28	1·92	3·30	1·81	8·31	3·07	4·85	2·68	3·91	1·70	3·50	43·19	E. F. Smith.
Pottstown, Penna.	150	2·82	3·32	1·33	3·45	2·80	5·65	4·29	4·89	4·80	4·64	1·88	1·10	40·97	Chas. Moore.
Zieglersville, Penna.	174	.....	.....	.....	.....	.....	.....	.....	4·00	3·96	4·77	1·75	5·76	.....	Phila. Water Dept.
Green Lane, Penna.	363	.....	.....	.....	.....	.....	.....	.....	3·20	6·51	5·20	1·69	4·21*	.....	Phila. Water Dept.
Green Lane, Penna. (automatic)	270	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1·43	.....	.....	Phila. Water Dept.
Pennsburg, Penna.	354	.....	.....	.....	.....	.....	.....	.....	.....	5·24	5·27	1·93	3.31	.....	Phila. Water Dept.
West Chester, Penna.	459	4·52	5·48	3·62	3·52	2·71	5·72	2·54	5·20	3·61	4·45	2·30	4·63	48·33	Dr. J. C. Green.
Reading, Penna.	200	4·42	4·23	3·09	3·05	1·81	6·05	3·83	2·99	3·80	4·20	0·81	2·73	41·01	E. F. Smith.
Lebanon, Penna.	498	4·35	4·22	3·70	2·89	2·98	8·54	2·66	2·68	4·46	5·93	1·42	3·28	47·41	S. B. Lehman.
Schuylkill Haven, Penna.	513	4·00	3·60	3·13	2·34	3·55	5·24	2·87	1·28	3·34	4·59	1·48	2·99	38·41	E. F. Smith.
Wilkesbarre, Penna.	546	4·48	2·38	2·55	2·70	5·28	8·52	7·08	0·88	3·19	3·12	1·45	1·99	44·12	Francis B. Hodge.

* Partially estimated.

LIST OF OBSERVERS ENGAGED BY THE DEPARTMENT.

NAME.		PLACE.
J. G. Hillsman,	since Dec. 15,	Frederick, Montgomery Co.
N. S. Renninger,	" July 24,	Green Lane, "
G. H. Hart,	" Sept. 9,	Pennsburg, "
G. W. Roth,	" Sept. 1,	Ottsville, Bucks Co.
Thos. Walton,	" Oct. 5,	Doylestown, "

In addition to the above, records from the following localities have been furnished, which greatly assist in arriving at proper conclusions, and for which we are indebted to the following parties:

Gen. W. B. Hazen, Chief Signal Officer, Washington.
T. F. Townsend, U. S. Signal Service, Philadelphia.
Mr. E. F. Smith, Chief Engineer Canals of Reading Railroad Company, Reading, Pa., for observations at Schuylkill Haven, Reading, and Browers (mouth of Perkiomen).

Mr. Thos. J. Beans	Burlington, N. J.
Mr. Francis B. Hodge	Wilkesbarre, Pa.
Mr. Charles Moore	Pottstown, Pa.
Mr. S. B. Lehman	Lebanon, Pa.
Mr. Millnor Gillingham	Fallsington, Pa.
Mr. M. McNeill	Princeton, N. J.
Mr. J. H. Heacock	Quakertown, Pa.
Miss Emily Kent	Phillipsburg, N. J.
Prof. S. J. Coffin	Easton, Pa.
Dr. J. C. Green	West Chester, Pa.
Prof. E. Pliny Chase	Haverford College, Pa.
Pennsylvannia Hospital	Philadelphia.

The report of Mr. Gowen on the detailed operations of the party is herewith appended.

PHILADELPHIA WATER DEPARTMENT.

January 23, 1884.

RUDOLPH HERING, ESQ.,
Assistant Engineer in charge of Surveys for a New Supply of Water.

SIR:—Herewith is submitted a report of the operations of the Hydrographic party connected with the surveys for a new supply of water, for the season ending January 1, 1884.

In accordance with instructions I reported for duty at the Water Department, June 24, and after making the necessary arrangements

for field and office work, proceeded, June 26, to Schwenksville, in the Perkiomen division, where headquarters for the party were established for the season.

STREAM GAUGING.

As the Perkiomen division is the most extensive, my instructions were to make a beginning on that side, and accordingly explorations and surveys of all those streams were immediately begun in order to establish gauging points.

It was proposed at first to use as far as possible current meters for gauging, but investigation showed that little could be done to advantage with those instruments under the ordinary conditions of the summer flow of the streams. These natural channels are very rough and of considerable width, showing everywhere the marks of the high flows of the winter and spring months, and the inclination of their beds are, as a rule, considerable, the streams forming, in most cases, a constant succession of mill-ponds, with but short intervals between each dam and the head of the succeeding pond below. Besides, the extreme shallowness of all the streams in their normal summer condition rendered the use of the current meter impossible at points where there was a perceptible current.

Accordingly it was decided to build a number of low weirs or dams, and to measure the flow passing them. This method offered the advantage that the manner of observation is simple, taking but little time, and affording opportunities for continuous measurements whenever desired. The weirs were intended to gauge the ordinary summer or low flows, and the meters were to be used whenever the streams were too high to allow the weirs to act as such.

(*a*). *Perkiomen Division.*—Gauging points were decided upon at the following places in the Perkiomen division:

Perkiomen, above Green Lane.
Macoby, " " "
East Swamp Creek, at Sumneytown.
West Swamp Creek, at Zieglersville.
North East Branch, at Schwenksville.

As it would take considerable time to build the weirs, gauges were placed at the following points:

On the Perkiomen, in Shaw's meadow, above Green Lane.

On the Macoby, at the "foot log," above Green Lane, near the house of Mr. Hildebeitel.

On the East Swamp Creek, at Sumneytown, on the land of Daniel Krauss, below the turnpike bridge.

On the Perkiomen, at Frederick, below the stone bribge.

On the Perkiomen, at Schwenksville, at Longaker's dam.

On the Perkiomen, at Schwenksville, below Longaker's dam.

On the West Swamp Creek, at Zieglersville, below Leidy's bridge.

On the Northeast Branch, at Schwenksville, on the land of John Alderfer.

These gauges are made of inch boards, painted white, and graduated to hundreths of feet. In a majority of cases they were attached to 6″ x 8″ hemlock posts, which were firmly set into the banks of the stream, and in all cases the tops of the gauges were connected by levels with defined bench marks near by, the levels being repeated from time to time as occasion demanded. Regular daily observations of the heights of the streams, began as follows:

West Swamp Creek Gauge	June 27
Longaker's Dam	" 30
Gauge below Longaker's Dam	" 30
Frederick Gauge	July 2
Northeast Branch Gauge	" 7
East Swamp Creek "	" 12
Gauge on the Perkiomen above Green Lane	" 12
Gauge on the Macoby " " "	" 13

As soon as it was decided to use weirs (about July 15) measures were taken to start work upon the Perkiomen weir, on Land owned by Mr. Shaw of Philadelphia, situated at Green Lane, plans having been prepared for that purpose, but on seeing Mr. Shaw, it was learned that he intended to build a dam which would flood our weir location. Finding a new location and making new arrangements occasioned delay, but work was started on the weirs as follows:

Macoby Weir	July 26
East Swamp Creek Weir	" 30
Perkiomen "	Aug. 8
Northeast Branch "	" 9
West Swamp Creek "	Sept. 3

Regular daily measurements of the flow at these weirs began as follows:

Macoby Weir	Aug. 8
East Swamp Creek Weir	" 8
Perkiomen "	" 29
Northeast Branch "	" 27
West Swamp Creek "	Sept. 13

The Perkiomen weir is located about one and three-fourths miles above Green Lane, on the land of Michael Gettle. Access to the weir is obtained over the land of William Smith. The weir is built in a bed of compact gravel; the length of crest or overflow is 68·83 feet, and the depth of the water on the up stream side is about 17 inches below the crest. The method of construction of this weir, which is the same, except in a few details, as the East Swamp Creek, the Northeast Branch and the West Swamp Creek weirs, is as follows:

Two 8 inch by 10 inch hemlock sills were placed parallel to each other across the bed of the stream, extending on either side a considerable distance into the bank, and forming, when joined together, a "bed" frame about four feet wide. Against the upper side of the upper sill, which was carefully placed to a true line, 3 inch tongued-and-grooved hemlock planks were placed in a dug trench, and then driven to a depth varying from 2½ to 3½ feet below the sills. These planks were spiked to the sill, and against them another 8 inch by 10 inch sill was then placed and firmly bolted to the planks and other sill, with three-quarter inch bolts, at intervals of about 2½ feet. The upper ends of the sheeting planks were allowed to project above the sills, and were stiffened by pieces of 6 inch by 8 inch timber placed against the down stream side, and to the up stream side were fastened the crest pieces, with five-eighth inch lag screws, placed 18 inches apart.

The crest pieces were made of well-seasoned oak plank, two inches thick and eight inches wide, carefully worked to true lines and surfaces, the upper edge, over which the water passes, presenting a horizontal face, one inch wide, with a beveled face for the remaining thickness. The crest pieces project from four to five inches above the timbers below, and their ends are either butted or mortised together. In the former case the joints are covered on the up stream side with thin iron plates, to prevent possible warping or leakage.

The upper face of the bed-frame is covered with two-inch plank, four to five feet in length, forming the apron of the weir. In the

Perkiomen weir this apron was surmounted by another, placed about a foot above, and the intervening space filled with heavy stones and gravel, forming a crib. The apron extends at either end for a considerable distance beyond the ends of the overflow; and the weir was further loaded by filling these parts of the apron with heavy stones. The up stream side of the sheeting, and the banks near the ends of the dams, were well puddled. The sheeting at the ends of the overflows was carried to a height, varying in the different weirs, from one to two feet above the level of the crest, and at that elevation extended into the banks.

(To be concluded.)

METHODS IN PHYSICAL ASTRONOMY.—Physical astronomy is a science which is altogether modern and for the most part contemporaneous. Its foundation was the discovery of telescopes. The telescopic harvest was so nearly exhausted by Herschel that the need of further assistance was generally felt. Arago sought help from polarization and his investigations prepared the way for spectral analysis. The small mass of matter which constitutes the chemical molecule, when it vibrates freely in the gaseous condition, sends out a special system of waves which varies with the chemical character of the molecule. The system of luminous waves may be compared to the system of sounds given by a vibrating cord, a system which depends firstly, upon the length of the cord, secondly, upon the volume, the timber and other circumstances which accompany the vibration. In the preliminary steps of spectral analysis we find the names of Wollaston, Fraunhofer, Sir John Herschel, Talbot, Miller, Wheatstone, Swanmasson and Foncault. Kerschof and Bunsen made a synthesis of all these efforts and brought the method into its present general and practical form. When spectral analysis was presented to the scientific world it held in one hand cæsium and rubidium, in the other a list of metals recognized in a star situated at a distance which is almost inconceivable. The subsequent discovery of telluric bands and the elective absorption exercised by atmospheric vapor prepared the way for the study of planetary atmospheres, which, when it becomes more complete, will show whether our atmosphere represents a type which is everywhere reproduced, or whether the varieties of atmospheric composition will lead us to admit the appearance and the development of life in media which are essentially different. The most recent method of physical astronomy is photographic. It has already brought a marvellous help to scientific study. The first image of a fixed star upon the daguerrean plate was that of the sun. It was obtained by Messrs. Fizeat and Foncault, the authors of the admirable methods of measuring the velocity of light, on the second of April, 1845. During the same year photographic impressions of fixed stars were obtained in the United States, and soon afterwards Rutherfurd and de la Rue produced their beautiful photographs of the moon. Rutherfurd, Gould and Draper

extended stellar and nebular photography and Janssen crowned the work by his solar photographs, some of which resulted from an exposure of less than $\frac{1}{100000}$ of a second. The photographic plates which are now prepared are not only sensitive to all the elementary rays which excite the retina, but they even extend their power into the ultra violet regions and into the opposite regions of obscure heat, in both of which the eye is equally powerless. Well then may Janssen say, that "the photographic plate will soon be the true retina of the savants."—*Lumiere Electrique*, April 12, 1884.

SOLAR MOTOR AND SOLAR TEMPERATURE.—After experiments extending over twenty years and involving the construction of various different forms of apparatus, Ericsson has manufactured a solar boiler by which he obtains a pressure upon the piston of 35 pounds to the square inch and a velocity of 120 turns per minute. Such a motor may be favorably employed in hot countries. From the amount of heat which is developed in the apparatus the inventor deduces a solar temperature of 1,303,640°F., and he gives reasons for believing that this temperature is inferior to reality.—*La. Nature*, April 5, 1884.

HIRN'S ACTINOMETER.—M. Hirn has invented an absolute actinometer, which is based on the following principle: A saturated vapor, contained in a closed recipient, takes a tension which corresponds to the lowest temperature of the enclosing walls. Imagine a still, the body of which is exposed to the sun, while the worm and the receiver are placed in the shade but in the open air. Place in the still a volatile liquid and make a vacuum in the apparatus, with the exception of the vapor which arises from the liquid. If the sky is completely covered the whole apparatus will be at the same temperature; the liquid will remain without distillation or condensation. As soon as the sky is uncovered and the sun's rays strike the still, the heat absorbed by the walls, instead of warming the liquid will make it boil, at the tension which corresponds to the minimum temperature of the apparatus and that of the refrigerant and the reservoir. If the surface of the latter is sufficient to disperse the heat continuously and rapidly in the surrounding air, the temperature of the whole apparatus will soon become stationary, and will be only slightly greater than that which will be indicated by a thermometer placed in the shade at the side of the refrigerator. The quantity of solar heat received in a unit of time will then be almost rigorously proportional to the quantity of liquid condensed in the unit of time. By the help of Regnault's equations the amount of solar heat absorbed by a known surface can then be regularly calculated, without resorting to any correction concerning accessory losses, the mass of liquid and of metal, etc. The best liquid for use seems to be bichloride of carbon.—*Chron. Industr.*, February 24, 1884. C.

SOAP ROOTS.—According to the investigations of A. Rosoll, (Monatshefte für Chemie, 1884, p. 104), the saponin which is dissolved in the sap of the living roots of *Saponaria officinalis* and *Gypsophila struthium*, can be separated in the form of small, irregular white lumps, either by drying or by treating thin slices with absolute alcohol or ether.—*Dingler's Journal*, April 30, 1884.

ALUMINIUM AND ALUMINIUM BRONZE.—At a recent sitting of the Glasgow Physical Society, Prof. Jamieson communicated the result of his researches upon the electric qualities of aluminium. The metal was nearly pure, its density 2,786, its electric resistance 1·96 times that of pure copper-wire of the same length and diameter. For wires of equal length and weight the resistance of aluminium is a little less than that of pure copper. The addition of a small quantity of aluminium to copper largely increases both the mechanical and the electrical resistance. The first experiments furnished specimens in which the electric resistance was 25 times as great as that of pure copper. Such an alloy would be very useful in the manufacture of resistance coils. On account of its lightness pure aluminium wire might often be found desirable in military telegraphy.—*L'Electrician*, April 1, 1884.

PALMIERI'S ATMOSPHERIC ELECTRICITY.—Palmieri's Memoir on the Laws and Origin of Atmospheric Electricity, has been faithfully translated into German, by Heinrich Discher. The memoir is the result of 32 years observations made at the meteorological station of Mt. Vesuvious. After announcing the laws of atmospheric electricity, the illustrious professor describes the ingenious apparatus and the original methods of experimenting which he adopted in order to determine those laws, and which enabled him to observe the electrical state of the air under clear, cloudy, and rainy skies, and during volcanic eruptions. He attributes the atmospheric electricity to the accumulation of watery vapor in the air under the form of cloud, mist or rain.—*L'Electrician*, April 1, 1884.

NEW ELECTRO-MAGNET.—Sig. B. Ricco, of Palermo, rolls a long band of sheet iron around a nucleus of soft iron, insulating the different layers of the band by oiled paper. One pole is connected with the nucleus, to which the interior extremity of the band is soldered, and the other is connected with its exterior extremity. The current, in traversing the band, magnetises not only the nucleus but also each layer of the band, which thus plays the double role of conductor and of magnetic substance, thereby condensing the lines of force, and producing a great concentration of power.—*L'Electricité; Les Mondes*, March 8, 1884.

TANNING BY ELECTRICITY.—M. L. Gaulard suspends hides in a bath of tannin, which is traversed by an electric current. The hydrogen which is set free by the current acts upon the leather and destroys the nitrogenous matter. After eight days emersion in this bath, the tannin solution is replaced by another which is more concentrated, and the direction of the current is changed by reversing the poles of the electrodes. The oxygen then acts upon the liquid, oxidizing the tannin and precipitating it in the cells which are formed by the gelatine and fibrine of the hide.—*Chron. Industr.*, February 17, 1884.

GASES IN STEEL.—Brustlein concludes, from a great number of observations, that iron and steel can be alloyed with nascent hydrogen at ordinary temperatures; that at a red heat this alloy is broken up, but that at the melting temperature of steel it may again be alloyed with hydrogen with more or less energy.—*Soc. des Ing. Civ.*, April, 1883 C.